VOL-VIII NO-4

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

APRIL 1921

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. VIII April, 1921 No. 4

The Summer Meeting

THE 1921 Summer Meeting at West Baden promises to be the largest in the history of the Society if the number of responses to the first announcement is accepted as a criterion. One week after the mailing of the first folder over 150 members had forwarded their reservation blanks. This emphasizes the necessity of making early application for hotel accommodations if the better locations are desired.

The Society is unusually fortunate in having secured the acceptance of Sir Dugald Clerk, the noted British scientist, of an invitation to attend the Summer Meeting and address the members on the fundamental theories on which the internal-combustion engine is based. In 1878, long before the advent of the automobile, Sir Dugald Clerk presented papers disclosing the results of his study and development of the gas engine. He has since devoted his life to research work in the internal-combustion engineering field and is responsible for much of the thermodynamic theory which has formed the basis of our present-day engine design. His writings are well known and appreciated by all who have made a thorough study of the theory of the internal-combustion engine. Sir Dugald Clerk plans to review his research study from its earliest stage to the present time, emphasizing the several fundamental theories as they were developed and summarizing these in a manner that will make them of the greatest value to the engine designer. We feel sure that our members will appreciate the unusual importance of this paper, and we expect extraordinary interest to be shown in the discussion which will follow its presentation.

Technical Sessions and Recreation

Progress is being made in the arrangement of the various technical sessions which will be devoted to the topics of Research, Fuel, Aircraft, Farm Power, Highways, and Engineering as a Sales Stimulus. The question of bettering the efficiency of existing automotive engines to improve their economy will be treated at the Fuel Session. This important factor in the fuel problem is often underestimated because of the usual tendency to concentrate on future development and new designs. One paper will disclose an interesting research study toward the development of a high-compression oil engine for automotive purposes and the engineering reasons for its desirability. The basic economic reasons for the present position of commercial aviation in the United States are receiving the attention of one of the Aviation Session authors and the recommendations he will offer for a strengthening of aircraft as transportation media should serve to promote the future of this branch of aviation. The powerplant of the airplane of the future will be treated at this session and some rather unconventional departures in design and installation will be presented. Great interest has been shown in the work of certain universities in the tractor field and it is hoped that one contribution from this source will be submitted at the Farm Power Session. The rather basic problem of an economical operating speed for tractors still seems to be of great importance in the application of automotive equipment to the farm and its discussion will be continued. There will be only one paper on highways, it being the intent of the Society to keep its members informed of the progress in highway research in this manner at each of the national meetings. The complete program of papers will be published just as soon as it is definitely arranged.

The arrangement and supervision of the sports program are progressing under the direction of Howard A. Coffin, who was assigned this task by C. F. Scott, chairman of the Meetings Committee. The unusually adequate facilities for sports contests at West Baden will assure a most entertaining week and enable the members to demonstrate their ability in golf, tennis, baseball, bowling, track and field events, and trap shooting. Letters inviting subscriptions to the sports fund have been sent to the companies in the industry and several have already proved their interest in the success of this phase of the meeting. The list of sport events will be published early enough to allow the members to engage in a suitable amount of spring preparation and report in top form for participation in the various contests.

The impression seems to be prevalent among some of the automotive companies that the Society is planning an extensive exhibit of a commercial nature at the Summer Meeting. This is not the case. The past custom of running tests of a purely engineering character in connection with the technical sessions is to be continued. The tractor men are planning a series of tests similar to those at Ottawa Beach and other branches of automotive engineering will probably receive similar treatment. There is however no intention of accepting exhibits which are strongly commercial in their scope.

The attention of those who intend to see the 500-mile race at Indianapolis on Monday following the Society Meeting is directed to the arrangement whereby members can secure seats in a section especially reserved for the

Society by so stating when ordering tickets from the Indianapolis Speedway Co. These seats are $7 each, directly across from the pits and just beyond the finish line.

Transportation Arrangements

The Society has succeeded in securing concessions from the railroad authorities in the way of reduced fares for the Summer Meeting. Round-trip tickets will be sold to the members at a reduction of 25 per cent. Some of the territories covered by certain of the passenger or trunk line associations would not agree to a reduction plan, but fortunately the territories where the plan is effective contain a very large percentage of the membership. The Mid-Western automotive centers such as Detroit, Cleveland, Chicago, Toledo, Indianapolis, and Dayton are all included. The Eastern centers, New York City, Philadelphia, Washington, Rochester, Pittsburgh and Buffalo will be included in the Eastern area. The only Society Sections which are not included in the agreement are Minneapolis and Boston. The railroads in New England, the South and West would not grant the fare reductions but members in these territories can purchase tickets to a point in the reduced fare area and receive the benefit of the reduction from this point to West Baden and return.

Plans are being made to run a special train from the East which will enable the members in the New York, Philadelphia and Boston territories to leave Monday forenoon and arrive at West Baden Tuesday in time for the opening of the Standards Committee Meeting. Particulars of this train and a detailed explanation of the reduced fare plan will reach the members shortly in the second Summer Meeting folder.

Undoubtedly many of the members in the Mid-Western territory will consider driving to West Baden. Reports received by the Meetings Committee indicate that there are many fine roads leading into Indianapolis and thence to West Baden. A map of the more important routes is now being prepared and will be mailed to the members for their use in planning the trip by automobile.

Remember the dates, May 24-28; the place, West Baden, Ind.; the numerous professional and recreational attractions; and send in your application for rooms early.

MARCH COUNCIL MEETING

THE meeting of the Council held on March 15 was attended by President Beecroft, First Vice-President Horning, Second Vice-Presidents Bachman and VanBlerck, Councilors Pope and Davis, Dr. H. C. Dickinson of the Bureau of Standards, Chairman C. A. Adams of the Engineering Division of the National Research Council, Chairman Scott of the Meetings Committee, and Secretary Clarkson.

Membership

One hundred and thirty applications for membership and enrollment were approved, 2 for Service Member, 2 for Foreign Member, 40 for Member, 57 for Associate, 27 for Junior and 2 for Student Enrollment. C. A. Bennett, A. A. Remington and W. M. VanDeuser were transferred from Member to Foreign Member grade; Theodore Hoffman from Associate to Foreign Member; Matthew J. Farrell, A. Gilson, H. G. Rendall and Harry M. Rugg from Associate to Member; Arthur A. Bull, C. D. Hanscom, Harold T. Youngren, E. R. Godfrey from Junior to Member.

Standards Matters

The following appointments to membership on the Standards Committee were made with assignment as indicated:

- G. J. Mead—Chairman Powerplant Subdivision of Aeronautic Division
- H. E. Derr—Truck Division
- W. H. Bassett—Non-Ferrous Metals Division
- W. R. Webster—Non-Ferrous Metals Division
- Samuel Tour—Non-Ferrous Metals Division
- C. E. Jeffers—Frames Division
- Victor Preston—Passenger Car Body Division
- G. E. Goddard, Vice-Chairman—Passenger Car Body Division

The Passenger Car Division was established as a new division of the Standards Committee. The lack of a division with general jurisdiction such as that which the name of the new division indicates has been felt from time to time when prompt handling of various subjects coming before the Standards Committee appeared desirable. It is intended that the new Division shall handle some subjects jointly with other divisions.

In response to a demand from many members of the Society, it was decided to establish an Axle and Wheel Division to consider in due course standard suggestions that have arisen in connection with various unsprung structural chassis elements, not including tires and rims. It is expected that this division will have an important part in the further formulation of hub standards. The personnel of the division will be announced at an early date.

David Sternbergh was appointed as the representative of the Society on the Sectional Committee on Gears of the American Engineering Standards Committee.

With reference to the receipt of the Report of the Tellers of Society Letter Ballot on Adoption of Standards under date of March 14, it was decided to not include in the next set of new date sheets the recommendation of the Engine Division with regard to muffler sizes and mounting, in view of the fact that 18 negative votes were cast for specific reasons of weight against the recommendation.

Earle Buckingham was nominated in place of H. T. Herr as the representative of the Society on the National Screw Thread Commission.

Meetings

It was reported that the total net expense of the 1921 Winter Meeting of the Society was $4,466.63. The corresponding figure for the 1920 Annual Meeting was $6,896.11.

Chairman Scott of the Meetings Committee reported that his committee feels that the success of the Semi-Annual Meeting of the Society to be held at West Baden May 24 to 28, was already assured so far as attendance and professional value are concerned.

Research

The plans under consideration following the establishment of the Research Department of the Society, were discussed comprehensively at the Council dinner in the evening. In addition to the Society officers who participated in the sessions held during the day, there were in attendance Past-Presidents Riker and Manly, Prof. R. M. Anderson of Stevens Institute of Technology, Prof. E. H. Lockwood of Yale University, Prof. G. B. Upton of Cornell University, Prof. C. A. Adams of Harvard University, C. B. Veal and Herbert Chase. Unanimous approval was expressed of the program that has been formulated in a general way for the collection, study, collation and dissemination of fundamental engineering knowledge of special importance to the automotive industry currently. Very gratifying assurance was had of assistance and cooperation from the universities represented at the dinner.

Automobile Exhaust Gases and Vehicular-Tunnel Ventilation[1]

By A. C. Fieldner,[2] A. A. Straub[3] and G. W. Jones[4]

Annual Meeting Paper *Illustrated with* Photograph and Charts

THE data given in this paper were obtained in the course of an investigation undertaken by the Bureau of Mines in cooperation with the New York and New Jersey State Bridge and Tunnel Commissions to determine the average amount and composition of the exhaust gases from motor vehicles under operating conditions similar to those that will prevail in the Hudson River Vehicular Tunnel. A comprehensive set of road tests upon 101 motor vehicles including representative types of passenger cars and trucks was conducted at the Pittsburgh Experiment Station of the Bureau of Mines in accordance with a program suggested by C. M. Holland, chief engineer of the tunnel commission.

The tests were started on Dec. 1, 1919, and were completed on Sept. 30, 1920, thus covering both winter and summer operating conditions. The cars tested were taken at random from those offered by private individuals, corporations and automobile dealers of Pittsburgh, and the tests were made without any change in carbureter or other adjustment. The results can therefore be taken as representative of motor vehicles as they are actually being operated on the streets at the various speeds and grades that will prevail in the tunnel. Furthermore, the information obtained in this investigation can be applied also to ventilation problems of other vehicular tunnels and subways, several of which are under construction or are proposed in other cities of the United States.

The motor vehicles tested comprised 101 automobiles and trucks of six representative classes as given in Table 1.

TABLE 1—CLASSES OF MOTOR VEHICLES TESTED

Class	Description	Number of cars tested
1	Five-passenger cars	19
2	Seven-passenger cars	13
3	Trucks up to 1½ tons	12
4	Trucks from 1½ to 3 tons inclusive	22
5	Trucks from 3½ to 4½ tons inclusive	17
6	Trucks of 5 tons and over	18
	Total	101

Twenty-four cars were tested under winter conditions between Dec. 1, 1919 and Feb. 6, 1920; and 77 cars were tested under spring and summer conditions between March 11 and Sept. 30, 1920.

Test Conditions and Methods

In the winter series, all cars were tested under the following conditions:

(1) Car standing and the engine racing
(2) Car standing and the engine idling
(3) Car accelerating from rest to 15 m.p.h. up a 3 per cent grade
(4) Car running 15, 10 and 3 m.p.h. up a 3 per cent grade
(5) Car running 15, 10 and 3 m.p.h. down a 3 per cent grade
(6) Car accelerating from rest to 15 m.p.h. on a level grade
(7) Car running 15, 10 and 3 m.p.h. on a level grade

Fig. 1—Two and One-Half-Ton Truck Equipped with Gasoline Measuring Apparatus and the Exhaust Gas Sampling Tube Which Were Used in Connection with the Tests

In the summer series the general test conditions were simplified by omitting the racing, idling and accelerating tests in most cases as sufficient data were obtained in the winter tests to show that these particular test conditions were of minor importance in estimating the total quantity of carbon monoxide generated in the tunnel. A 6-m.p.h. test was substituted for the 3-m.p.h. test as being more representative of slow-moving traffic and a 20-m.p.h. test on a level grade was added for passenger cars. The remaining tests were the same as in the winter series. Most of the heavy trucks were tested at 6 and 10 m.p.h. only, as they could not be speeded to 15 m.p.h.

The trucks and the seven-passenger cars were tested with full load at their rated capacity and also with no load other than the two observers, chauffeur and apparatus weighing 50 lb. The five-passenger cars were tested with the light load only, consisting of three men and the apparatus.

All cars were tested in the same condition as received, without any change in carbureter or other adjustment, and with the same brand of gasoline as was being used in the car. Fig. 1 shows a 2½-ton truck equipped with gasoline measuring apparatus located in front of driver's seat and the exhaust gas sampling tube which can be seen back of cab ready for test.

The gasoline measuring apparatus shown in Fig. 2

---

[1] Published with the permission of the Director of the Bureau of Mines and the Chief Engineer of the New York and New Jersey State Bridge and Tunnel Commission.

[2] Supervising chemist, Bureau of Mines Experiment Station, Pittsburgh.

[3] Mechanical engineer, Bureau of Mines Experiment Station, Pittsburgh.

[4] Assistant physical chemist, Bureau of Mines Experiment Station, Pittsburgh.

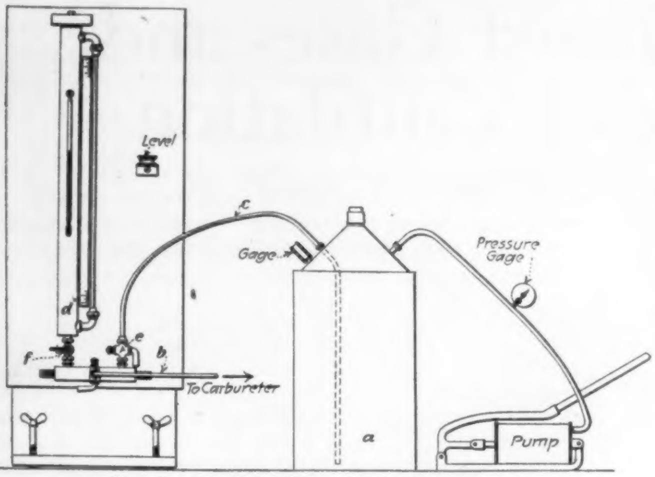


FIG. 2—GASOLINE MEASURING APPARATUS

was connected directly to the carbureter and to a reserve supply of gasoline *a*, through the copper pipes *b* and *c*, respectively. As the car crossed the boundary lines of the test course at the predetermined speed for the test the gasoline feed was switched from the reserve supply to the measuring tube *d* by closing the cock *e* and opening *b*. At the end of the test course, a reverse operation of these cocks switched the supply back to the reserve supply tank.

The exhaust gas sampling apparatus is shown in Fig. 3. A 1/4-in. copper tube, *g*, bent at right angles, with the opening turned toward the engine was introduced into the exhaust pipe between the engine and muffler. The exhaust gas pressure was sufficient to maintain a rapid stream of gas through the heavy-walled rubber tube, *h*, connected to the glass tee, *i*, on the sampler board. The main stream of exhaust gases passed on through the rubber tube, *h*, and was discharged into the atmosphere through the water seal, *j*, thus preventing any air from being sucked back into the sample.

The exhaust gas sample was collected continuously at a uniform rate over the whole period of the test, in a 250-cc. glass sampling tube connected to the downward branch of the tee, *i*. One observer gave his entire attention to regulating the flow of a 5 per cent solution of sodium chloride previously saturated with exhaust gas from the sample tube, by adjusting the screw clamp at the lower end of the tube.

The samples were analyzed in duplicate for carbon dioxide, oxygen, carbon monoxide, hydrogen and methane on a laboratory type Burrell-Orsat apparatus[5] as used in the Bureau of Mines for a complete gas analysis. The carbon dioxide was absorbed in a potassium hydroxide solution, the oxygen in potassium pyrogallate, the carbon monoxide in two bubbling pipettes in series containing an acid cuprous chloride solution and the hydrogen, methane and any residual carbon monoxide were determined by slow combustion in the presence of a hot platinum wire.

In this method of analysis any gasoline vapor and other hydrocarbons appear as methane. In other words, the analysis gives the equivalent methane value for all the hydrocarbons in the exhaust gas, and the result is correct as regards the carbon content for computing the total volume of exhaust gases from the gasoline consumption and the carbon content of the gasoline. This relation was checked to within 6 per cent by actual measurement of exhaust gas into a 50-cu. ft. container.

The determination of the gasoline vapor as methane causes the hydrogen value in the analysis to be somewhat less than its true value. This error in the hydrogen value has no effect on the calculation of the true value of the carbon monoxide, carbon dioxide and methane equivalent of the total hydrocarbons.

All the streets in the 3-per cent grade course, Fig. 4, were paved with asphalt and in excellent condition. While there was a fair amount of traffic, no trouble was experienced from stoppage by other vehicles due to the absence of much traffic on the few intersecting streets.

The Stanton Avenue portion of the level course, Fig. 5, outside of Highland Park was asphalt in good condition; the remainder of the course in the Park was macadam in rather bad condition. There were no deep holes, but the surface was worn and uneven.

METHODS OF COMPUTING RESULTS

The total volume of exhaust gases produced per gallon of gasoline consumed was computed from the analysis of the exhaust gases and the weight and analysis of the gasoline. This computation is based on the assumption that all the carbon in the gasoline appears in the exhaust gases. As a matter of fact, there is a small error due to solid particles of carbon in the exhaust and on the engine surfaces and the leakage of gasoline into the crankcase. This error can be partly compensated for or even exceeded in some cases by lubricating oil burning in the cylinders. The total error is probably negligible. Some tests were made with the engine idling, the exhaust gases being collected and measured in a 50-cu. ft. calibrated gas tank. The measured volumes checked to

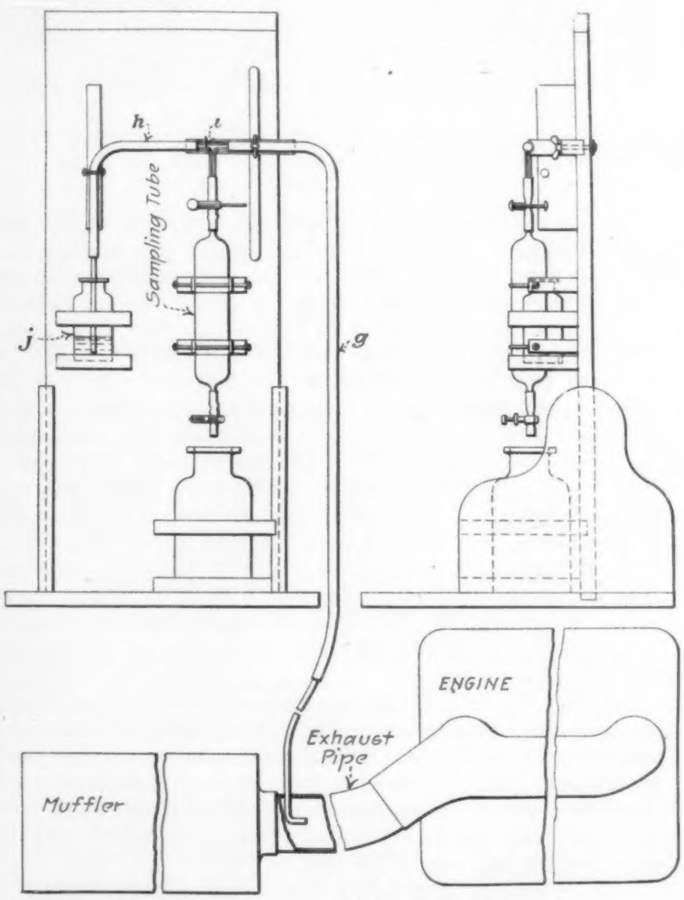


FIG. 3—EXHAUST GAS SAMPLING APPARATUS

[5] See Bureau of Mines Bulletin No. 42 entitled The Sampling and Examination of Mine Gases and Natural Gas by G. A. Burrell and F. M. Seibert, p. 43.

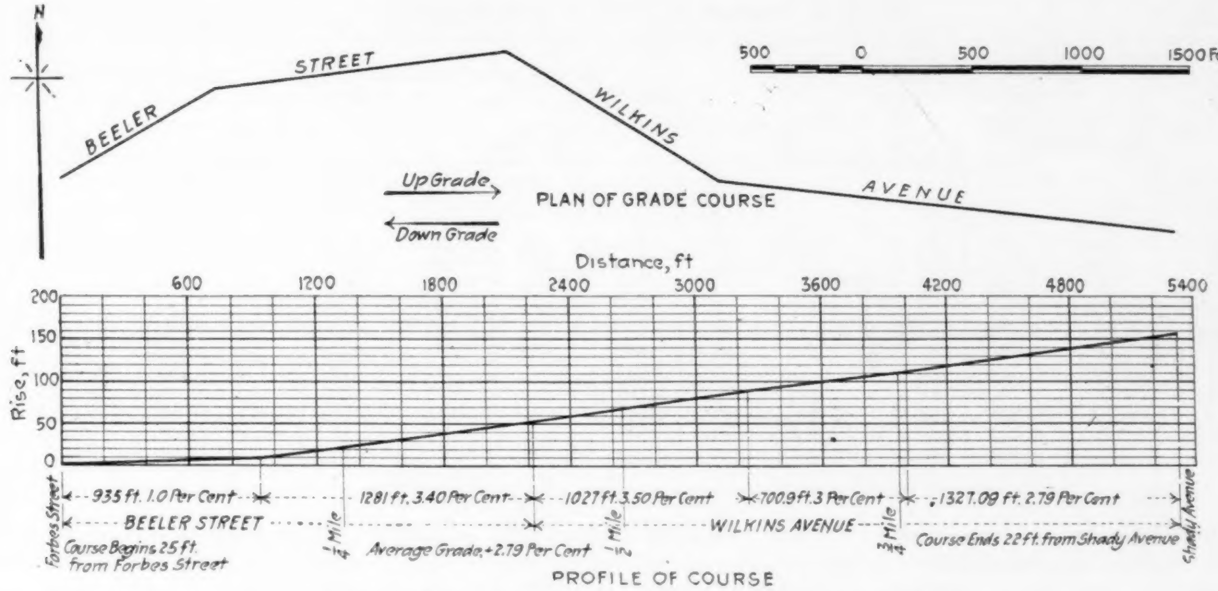


FIG. 4—PLAN AND PROFILE OF THE 3-PER CENT GRADE COURSE

within 6 per cent of the volume computed from the analysis in the usual manner.

The volume of exhaust gases was computed by the following method:

From Gasoline Analysis

where

a = The specific gravity of the gasoline at 60 deg. fahr.
b = The percentage of carbon in the gasoline
8.33 = The weight of 1 gal. of water at 60 deg. fahr., lb.
$8.33ab$ = Lb. of carbon in 1 gal. of gasoline (1)

From Gas Analysis

where

c = The percentage of carbon dioxide, by volume, in the exhaust
d = The percentage of carbon monoxide, by volume, in the exhaust
e = The percentage of methane, by volume, in the exhaust
0.1158 = The weight of 1 cu. ft. of carbon dioxide at 65 deg. fahr. and 29.92 in. of mercury, lb.
0.0732 = The weight of 1 cu. ft. of carbon monoxide at 65 deg. fahr. and 29.92 in. of mercury, lb.
0.0420 = The weight of 1 cu. ft. of methane at 65 deg. fahr. and 29.92 in. of mercury, lb.
0.1158×0.272[6] $= 0.0316 =$ lb. of carbon in 1 cu. ft. of carbon dioxide at 65 deg. fahr. and 29.92 in. of mercury
0.0732×0.429[6] $= 0.0314 =$ lb. of carbon in 1 cu. ft. of carbon monoxide at 65 deg. fahr. and 29.92 in. of mercury
0.0420×0.75[6] $= 0.0315 =$ lb. of carbon in 1 cu. ft. of methane at 65 deg. fahr. and 29.92 in. of mercury
$0.0316c \times 0.0314d \times 0.0315e$ = Total pounds of carbon in 1 cu. ft. of exhaust gas

This expression may be simplified by using the mean value 0.0315 as follows:

$0.0315\ (c + d + e)$ = Total pounds of carbon in 1 cu. ft. of exhaust gas ((2)

Dividing (1) by (2)

$8.33ab/0.0315\ (c + d + e) = 264.4ab/(c + d + e)$ = The number of cubic feet of exhaust gas per gallon of gasoline at 65 deg. fahr. and 29.92 in. of mercury

The numerator of the above expression is constant for each gasoline and represents the total cubic feet of car-

[6] Ratio of the atomic weight of carbon to the molecular weight of the gas.

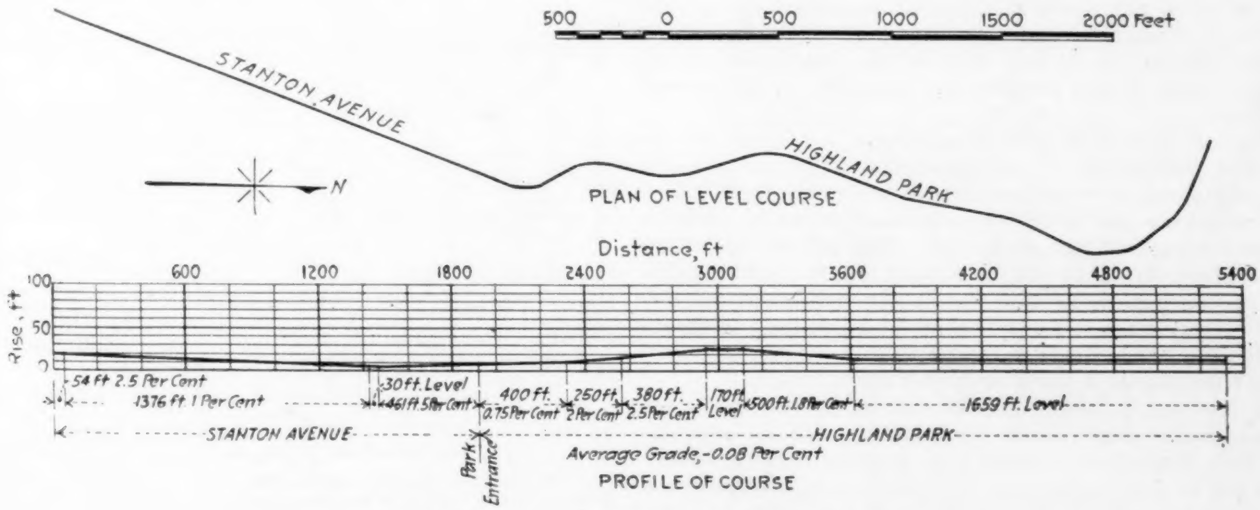


FIG. 5—PLAN AND PROFILE OF THE LEVEL COURSE

TABLE 2—ANALYSES OF GASOLINE USED IN TESTS

Kind	Sample Number	Specific Gravity at 60 Deg. Fahr.	Baumé Gravity at 60 Deg. Fahr.	Unsaturation. per cent	Distillation in 100-cc. Engler Flask, Temperature in Deg. Fahr.						Ultimate Analysis	
					First Drop	Per Cent 20	50	90	Dry Point	Average	Carbon. per cent	Hydrogen, per cent
A	1	0.713	66.4	2.5	88	151	225	381	441	239	84.3	15.7
A	9	0.710	67.2	...	84	149	234	385	421	241	84.4	15.4
AM	2	0.731	61.5	...	93	181	266	394	451	282	84.3	15.7
AM	3	0.743	59.2	1.5	95	192	271	405	457	275	84.5	14.5
AM	10	0.748	57.2	...	86	219	277	392	435	278	84.5	15.2
G	4	0.730	61.8	2.0	104	187	259	363	414	259	85.2	14.8
G	8	0.736	60.2	...	115	194	241	352	419	253	85.1	14.7
G	11	0.747	57.4	2.0	122	219	262	374	433	275	84.9	15.3
M	5	0.722	63.9	3.0	84	167	284	432	448	277	85.3	14.7
MM	6	0.742	58.7	2.5	80	201	302	432	448	289	86.0	14.0
B	7	0.796	45.9	2.0	115	199	248	381	430	264	88.3	11.7

bon containing gases, carbon dioxide, carbon monoxide and methane, that is produced by a gasoline of the given specific gravity and carbon content. The denominator varies with each test and represents the proportion by volume of carbon containing gases in 1 cu. ft. of the exhaust gas.

All cars were tested with the same brand of gasoline as was being used in the car at the time it was submitted for test. To avoid analyzing a large number of samples of the same brand, a large stock of each of the brands in use around Pittsburgh was obtained and carefully sampled and complete analyses of each sample are given in Table 2. The ultimate analyses, giving carbon and hydrogen content, were made by W. A. Selvig, analytical chemist of the Bureau of Mines, and the standard distillation tests and specific gravity determinations were made in the Bureau's petroleum laboratory under the direction of E. W. Dean, petroleum chemist.

RESULTS OF TESTS

It is not possible to give the results of the individual tests of each of the 101 cars included in the entire investigation within the limited scope of this article. Complete results and full details will be published in a bulletin by the Bureau of Mines and a more extensive summary will be included in a forthcoming report of the Chief Engineer of the New York and New Jersey State Bridge and Tunnel Commissions. The present paper will therefore be confined to a presentation of the average exhaust gas analyses, gasoline consumption and the quantity of carbon monoxide produced and a discussion of the application of this data to the ventilation of vehicular tunnels and present day economy in the use of gasoline.

Figs. 6, 7, and 8 give a graphical summary of the average percentage of carbon monoxide in the exhaust gas, the gasoline consumption and the cubic feet of carbon monoxide per hour for each class of motor vehicles under the various test conditions. The volume of carbon monoxide emitted is the important figure in the problem of ventilation, as this gas is the poisonous constituent of the exhaust gases that must be diluted with air so that its concentration in the tunnel atmosphere will at no time exceed 4 parts in 10,000 parts of air.

All the results shown in the curves, except those for five-passenger cars which were tested with an average load only consisting of three men and the apparatus, are averages of two tests, one with no load other than the chauffeur, two observers and 50 lb. of apparatus and the other with a load of full-rated capacity. Figs. 6 and 7 cover winter and summer tests respectively for passenger cars and light-speed trucks. All the heavy trucks were tested in the spring and summer and are shown in Fig. 8.

It will be noticed from the plotted results that the average percentage of carbon monoxide for each class of vehicles varies between 5 per cent as the minimum and 9 per cent as a maximum, except in the heavy truck class where the variation is between 4 and 8 per cent, the range of variation being the same. The larger percentages tend to be produced when the engine is racing, idling or running on light load on the low gear at 3 m.p.h., and on the low-speed level grade tests for summer conditions. However, the greatest amount of carbon dioxide per hour is generated under conditions of greatest load, when accelerating or running up grade at the highest speed. The relative quantity of carbon monoxide produced depends primarily on the gasoline consumption as shown at a glance by the similar rise and

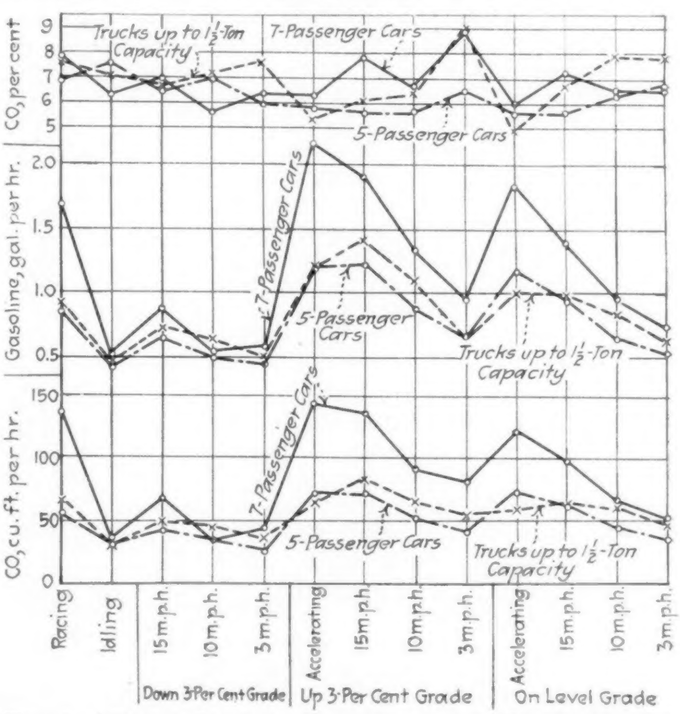


FIG. 6—AVERAGE GASOLINE CONSUMPTION AND PERCENTAGE AND QUANTITY OF CARBON MONOXIDE FOR PASSENGER CARS AND TRUCKS UNDER 1½-TONS CAPACITY TESTED UNDER WINTER CONDITIONS

fall of the "gasoline" and "cubic feet of carbon monoxide" curves.

The average percentage of carbon monoxide under all conditions of test for each class of vehicles was, five-passenger cars 6.5; seven-passenger cars 7.2; trucks up to 1½ tons capacity 6.9; trucks from 1½ to 3 tons inclusive, 6.3; trucks from 3½ to 4½ tons inclusive, 6.9; trucks of 5 tons and over, 6.4. The average percentages

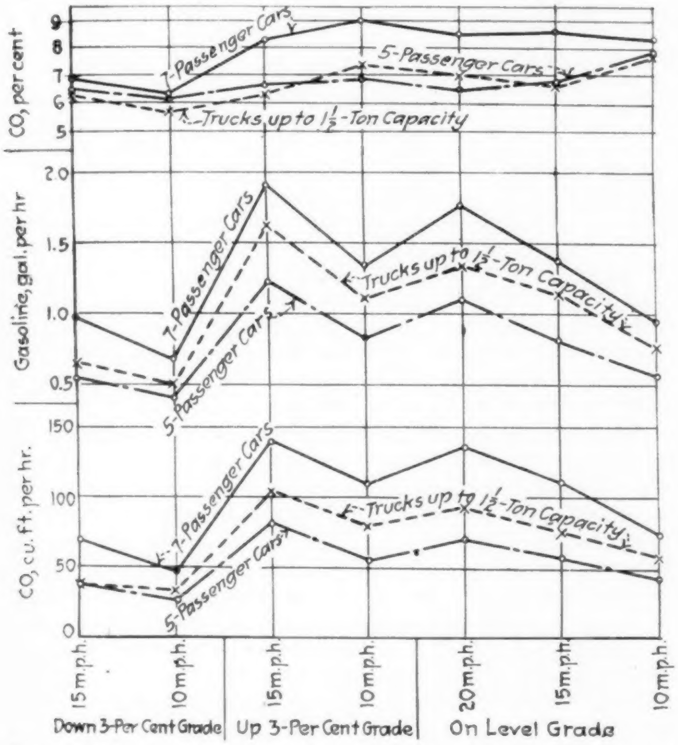


FIG. 7—AVERAGE GASOLINE CONSUMPTION AND PERCENTAGE AND QUANTITY OF CARBON MONOXIDE FOR PASSENGER CARS AND TRUCKS UNDER 1½-TONS CAPACITY TESTED UNDER SUMMER CONDITIONS

of carbon monoxide obtained on these tests is practically the same as those obtained by Hood, Kudlich and Burrell[7] in tests of gasoline mine locomotives with carbureters adjusted for the maximum power. They found that when the maximum power was being developed the gases usually contained from 5 to 7 per cent carbon monoxide, and that the carbon monoxide content could be

[7] See Bureau of Mines Bulletin No. 74 entitled Gasoline Mine Locomotives in Relation to Safety and Health by O. P. Hood, R. H. Kudlich and G. A. Burrell, pp. 66 to 68.

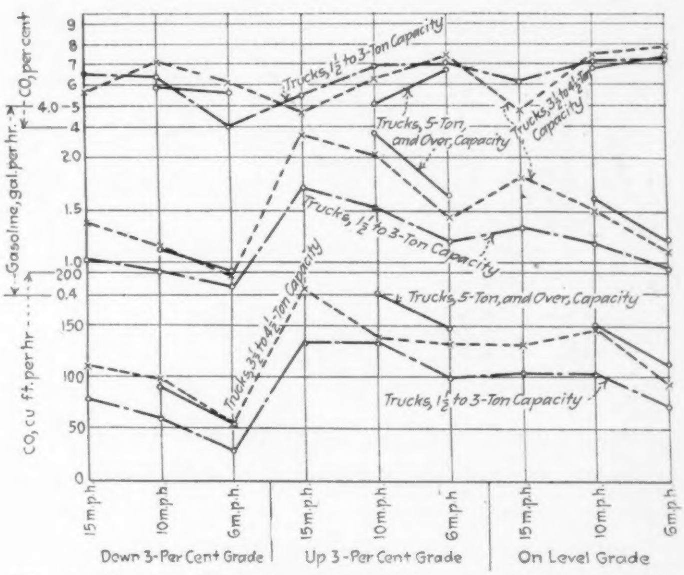


FIG. 8—AVERAGE GASOLINE CONSUMPTION AND PERCENTAGE AND QUANTITY OF CARBON MONOXIDE FOR TRUCKS OVER 1½-TONS CAPACITY TESTED UNDER SUMMER CONDITIONS

increased to as much as 9 per cent without reducing the power appreciably.

These investigators have also shown that the proportion of carbon monoxide in exhaust gases varies from zero to about 14 per cent, the amount depending on a number of variables, chief of which are

(1) Ratio of air to gasoline
(2) Completeness of the vaporization and mixing
(3) Speed of the engines
(4) Temperature of the air and the jacket water
(5) Quality and time of the spark
(6) Degree of compression
(7) Quality of the gasoline or other fuel

In view of this large number of variables it is not surprising that extremely large variations in exhaust gas composition were obtained in testing motor vehicles taken from ordinary service without any adjustment prior to the test. This is particularly true since they were driven in a variable manner with foot accelerator or hand throttle by different drivers over an approximately smooth course, yet one with some rough places requiring opening and closing of the throttle to maintain a constant speed.

It is, therefore, not possible to draw conclusions on the effect on exhaust gas composition of the various factors

TABLE 3—BEST AND POOREST RESULTS OBTAINED ON SEVERAL REPRESENTATIVE MAKES OF LOADED PASSENGER CARS AND TRUCKS

Car No.	Make of Car	Type of Vehicle	Speed on Level Grade, m.p.h.	Miles per gal.	Increase in Mileage, per cent.	Completeness of Combustion, per cent.	Exhaust Gas Analyses by Volume, Per Cent: Carbon Dioxide	Oxygen	Carbon Monoxide	Methane	Hydrogen	Air-Gasoline Ratio, lb.
1	C	Five-passenger car	15	27.30	105.8	100	13.0	2.6	0.0	0.0	0.0	16.7
9	C	Five-passenger car	15	13.26	.....	84	11.8	0.8	3.7	0.3	1.6	13.5
11	G	Seven-passenger car	15	18.61	66.8	93	9.3	5.4	1.3	0.0	0.1	20.1
10	G	Seven-passenger car	15	11.16	.....	61	7.5	2.1	9.3	1.4	4.0	10.7
84	X	¾-ton truck	15	15.39	44.5	90	10.7	3.9	1.7	0.5	0.2	16.6
76	X	¾-ton truck	15	10.66	.....	59	7.1	0.7	10.7	1.0	5.1	10.3
38	Y	3½-ton truck	10	6.55	36.2	87	12.9	0.3	1.9	0.8	0.4	13.9
57	Y	3½-ton truck	10	4.81	.....	65	7.5	0.8	10.6	1.0	4.9	10.2
44	D	Five-passenger car	15	10.26	.....	49	5.3	1.0	13.2	1.9	7.1	9.0

TABLE 4—EFFECT OF CARBURETER ADJUSTMENT ON GASOLINE CONSUMPTION AND EXHAUST GAS ANALYSIS

Carbureter Adjustment Needle Valve Turns	Gasoline Consumption		Exhaust Gas Analysis, Per Cent						Air per pound of gasoline, lb.	Completeness of Combustion, per cent	Remarks
	Gallons per mile	Miles per gal	Carbon Dioxide	Oxygen	Carbon Monoxide	Methane	Hydrogen	Nitrogen			
1	0.0670	14.9	13.4	1.7	1.2	0.2	0.0	83.5	14.5	95	8
1¼	0.0720	13.9	12.0	1.4	2.0	1.1	0.0	83.5	14.2	85	9
1 7/16	0.0940	10.6	10.2	0.3	6.4	0.8	2.4	79.9	11.8	74	10
1¾	0.1142	8.8	6.5	1.2	11.6	1.0	6.4	73.3	9.9	56	11

[8] Exhaust clear; mixture too lean to operate without the use of the air choke.

[9] Exhaust clear; operation satisfactory. Air choke one-quarter on during part of the test.

[10] Exhaust slightly smoky; operation satisfactory. Car had good "pick-up."

[11] Smoky exhaust; mixture seemed too rich for satisfactory operation.

just enumerated, except with regard to the ratio of air to gasoline or the carbureter adjustment.

A study of all the tests made shows that the variation in exhaust gas composition due to carbureter adjustment is far greater than any other factor. They do not throw much light on the advantage of any particular make or type of carbureter, nor should any conclusions be drawn as to the merits or demerits of any particular make of car. Table 3 gives a comparison of the best and poorest tests obtained on several well-known makes of passenger cars and trucks. Car No. 1 had the best gas analysis, and greatest mileage of any car tested. Car No. 44, also a five-passenger vehicle, had the poorest gas analysis and the lowest mileage in its class. Both cars operated without any apparent difficulty throughout the tests. Car No. 11 did not operate smoothly and lacked flexibility at low speeds due to the mixture being too lean. However, the mileage per gallon of gasoline was much higher than with the other cars in the same class. At speeds above 15 m.p.h. it operated smoothly and gave a good illustration of the tremendous quantity of fuel that can be saved by using lean mixtures. It should be noted that in each case the car with the leaner mixture shows the largest mileage per gallon of gasoline. The increase in mileage ranges from 36 to 106 per cent.

[12] With this mixture the engine develops about 85 per cent of its maximum power.

[13] See THE JOURNAL, November, 1919, p. 364.

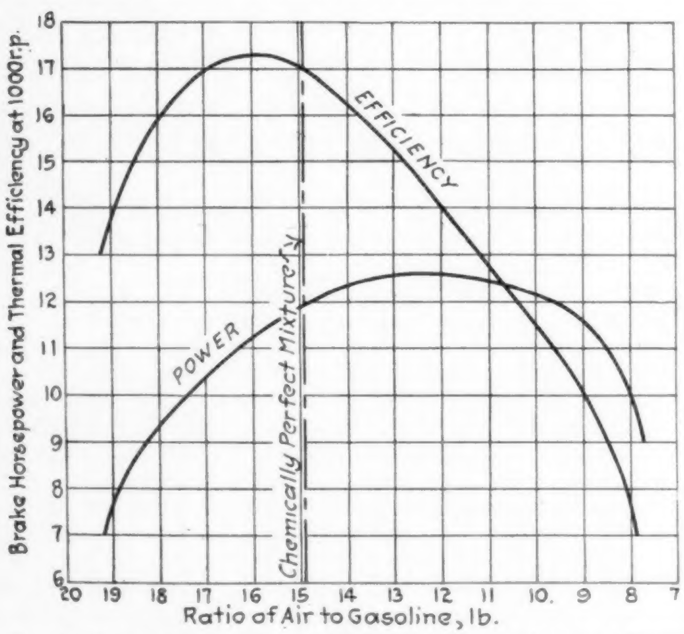


FIG. 9—CURVES SHOWING THE RELATION OF THE AIR-GASOLINE RATIO TO THE POWER AND THERMAL EFFICIENCY OF A FOUR-CYLINDER ENGINE OPERATING AT 1000 R.P.M.

The effect of various carbureter adjustments on an individual car is shown in Table 4. Before putting this car through the standard series of road tests the driver, an automobile mechanic, was asked to place the carbureter in good adjustment. He set it after the engine was warmed up to running conditions, at 1 7/16 turns of the needle valve. As shown in the table this setting produced 6.4 per cent carbon monoxide and 10.2 per cent carbon dioxide, a little better than the average analysis of all the cars tested. Tests were then repeated under identical conditions with both richer and leaner settings. It was found that 1¼ turns of the carbureter needle gave 12 per cent carbon dioxide and 2 per cent carbon monoxide and 31 per cent greater mileage; also the car operated satisfactorily. This car was a roadster with a four-cylinder engine having a bore of 4⅛ in. and a 4½-in. stroke. A Johnson carbureter was used and the intake air and the manifold were heated. The gasoline burned had a Baumé gravity of 66.4 deg. and a distillation of 10 per cent at 127 deg. fahr., 50 per cent at 225 deg. fahr. and a dry point of 441 deg. fahr, or an average of 239 deg. fahr. The tests were run on an asphalt pavement in good condition ascending a 3-per cent grade at 15 m.p.h.

This test is typical of the great majority of the passenger cars and trucks tested. The carbureters were invariably adjusted on the rich side for the greatest flexibility of operation rather than for the maximum economy of gasoline. One pound of ordinary fuel gasoline of today such as was used in the tests just described requires approximately 15 lb. of air for complete combustion. The maximum thermal efficiency is obtained at about 16 lb.[12] of air to 1 lb. of gasoline and the maximum power with 12 to 13 lb. of air.[13] Herein lies the reason for the use of rich mixtures. The average driver demands first of all power and flexibility of operation. He sets his carbureter adjustment rich enough to give good operation with a cold engine and for slow driving in heavy traffic, with plenty of reserve power for hill climbing and bad roads. If he errs somewhat on the rich side it does not become manifest in the loss of power, but only in the increased gasoline consumption which in many instances does not concern him at all. An inspection of the average thermal efficiency and power curves of Fig. 9 shows that the pro-

portion of air in the mixture can be reduced to 9 lb. of air to 1 lb. of gasoline with a loss of only 9 per cent in power, although the economy and the efficiency are tremendously reduced.

Fig. 10 shows the relation between the air-gasoline ratios and the percentage of carbon monoxide in the exhaust gas for 23 passenger cars and trucks, the average of light and full-load tests, tested under winter conditions at 15 m.p.h. running up a 3 per cent. grade. Fig. 11 covers 20 passenger cars and trucks tested under the same conditions in the summer; and Fig. 12 shows the same relation for 54 trucks of from $1\frac{1}{2}$ to 5 tons capacity and over, tested in the summer at 10 m.p.h. up a 3 per cent grade.

The air-gasoline ratios varied from 15.8 with about 0.5 per cent of carbon monoxide, to 9.0 with 13.0 per cent of carbon monoxide. The average air-gasoline ratio was 12.3 with an average carbon monoxide percentage of 6.4, practically the exact figure for maximum power. Obviously, carbureters are adjusted in practice for maximum power and not for maximum thermal efficiency and economy of gasoline.

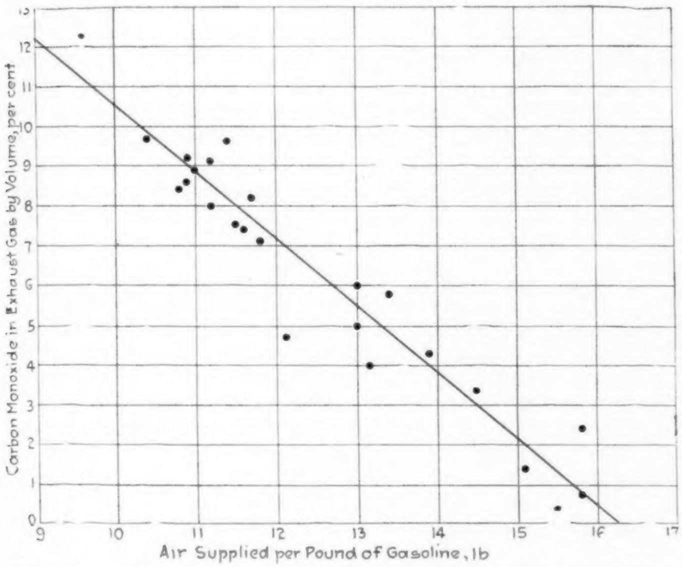


FIG. 10—AVERAGE RELATION BETWEEN PERCENTAGE OF CARBON MONOXIDE AND AIR-GASOLINE RATIO FOR PASSENGER CARS AND LIGHT TRUCKS TESTED UNDER WINTER CONDITIONS UP A 3-PER CENT GRADE

The results for the 54 trucks plotted in Fig. 12 show most strikingly the lack of attention paid to economical carbureter adjustment; the air-gasoline ratios are uniformly distributed over the entire range of mixtures on which it is possible to operate the engines.

The average loss of gasoline due to the continuous operation of a car at the point of maximum power is shown in Table 5, which gives computations from average exhaust gas analyses, heat in the gasoline and heat in the unburned exhaust gas constituents.

The completeness of combustion can also be calculated with sufficient accuracy directly by weight from the exhaust gas and by volume from the gasoline analyses as follows:

In making the calculation from the gasoline analysis if we let A designate the ratio of water vapor to carbon dioxide by volume on complete combustion which is equal to one-half the percentage of hydrogen divided by one-twelfth the percentage of carbon and assume the heat of combustion of carbon and hydrogen as 14,540 and 62,000 B.t.u. respectively, then the percentage of heat units due to carbon or B equals the percentage of carbon multiplied by 14,540 and divided by the sum of 14,540 times the percentage of carbon plus 62,000 times the percentage of hydrogen. Similarly the percentage of heat units due to hydrogen or C equals 62,000 times the percentage of hydrogen divided by the sum of 14,540 times the percentage of carbon plus 62,000 times the percentage of hydrogen.

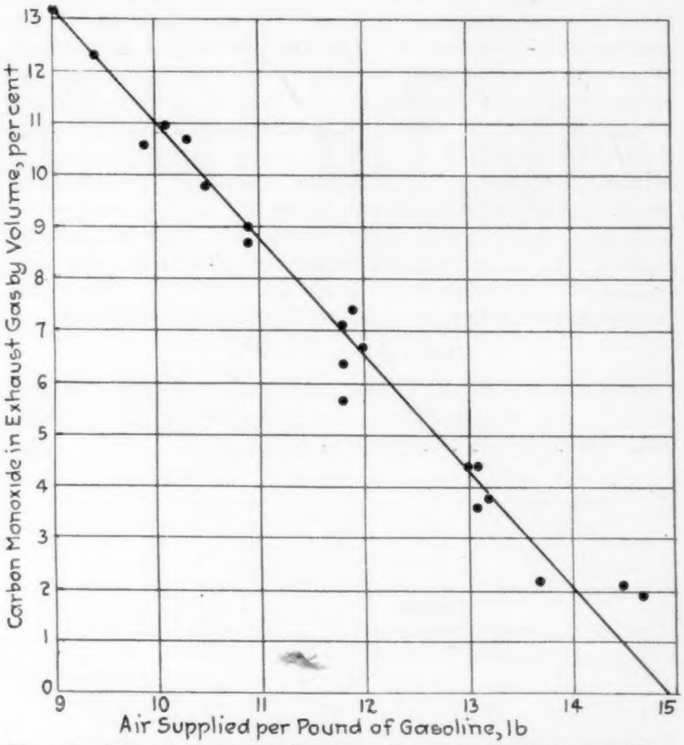


FIG. 11—AVERAGE RELATION BETWEEN PERCENTAGE OF CARBON MONOXIDE AND AIR-GASOLINE RATIO FOR PASSENGER CARS AND LIGHT TRUCKS TESTED UNDER SUMMER CONDITIONS UP A 5-PER CENT GRADE

In using the gas analysis if we designate the volume of carbon dioxide formed on complete combustion which is the sum of the percentages of carbon dioxide, carbon

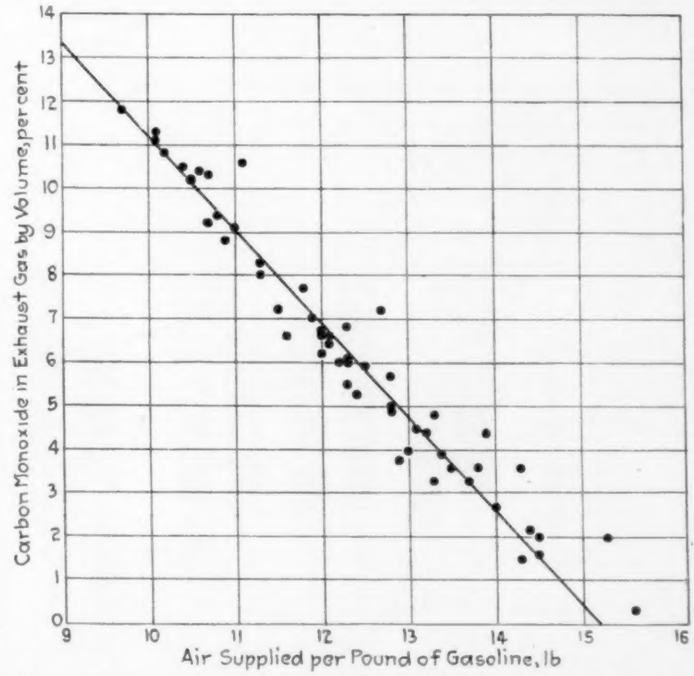


FIG. 12—AVERAGE RELATION BETWEEN PERCENTAGE OF CARBON MONOXIDE AND AIR-GASOLINE RATIO FOR TRUCKS OVER $1\frac{1}{2}$ TONS TESTED UNDER SUMMER CONDITIONS UP A 3-PER CENT GRADE

monoxide and methane by D and the completeness of the combustion of carbon which is the sum of the percentage of carbon dioxide plus three-tenths of the percentage of carbon monoxide divided by the sum of the percentages of carbon dioxide, carbon monoxide and methane by E, then the equivalent volume of water vapor formed on complete combustion equals the product of D multiplied by A. Likewise the completeness of the combustion of hydrogen or F equals unity minus the quotient of the sum of the percentage of hydrogen plus twice the percentage of methane divided by D times A. Hence the completeness of the combustion of the gasoline equals

$$(B \times E) + (C + F)$$

The factors A, B and C are practically constant for any given grade of gasoline. For gasolines used in these tests these factors averaged as follows:

Grade of Gasoline	Factors A	B	C
68-70	1.09	57	43
Motor	1.04	58	42
Benzol Mixtures	0.80	64	36

TABLE 5—AVERAGE COMPOSITION OF EXHAUST GAS, BY VOLUME, FROM TESTS OF 23 CARS, AT 15 M.P H.

	Level grade, per cent	Ascending 3 per cent grade, per cent
Carbon dioxide	8.9	9.6
Oxygen	2.3	1.3
Carbon monoxide	6.3	6.4
Methane	0.9	0.6
Hydrogen	3.0	2.9
Nitrogen	78.6	79.2
Total	100	100
Cubic feet of exhaust gases at 65 deg. fahr. and 29.92 in. of mercury	988	

Composition of Gasoline

Specific gravity	0.713
Carbon, per cent	84.3
Hydrogen, per cent	15.7
Calorific value, B.t.u. per lb.	21,300
B.t.u. per gal.	130,000

[14] Gross British thermal units per cubic foot at 65 deg. fahr. and 29.92 in. of mercury.

[15] See *The Automobile*, vol. 30, pp. 395 and 442.

[16] See the *Proceedings of the Institution of Automobile Engineers*, vol. 3, p. 293.

The exhaust gas from 1 gal. of gasoline on level-grade tests contains

$988 \times 6.3 = 62.2$ cu. ft. of carbon monoxide
$988 \times 0.9 = 8.9$ cu. ft. of methane
$988 \times 3.0 = 29.6$ cu. ft. of hydrogen

The total heat in the unburned gases per gallon of gasoline is

62.2×320[14] $= 19{,}900$ B.t.u.
$8.9 \times 1{,}000 = 8{,}900$ B.t.u.
$29.6 \times 322 = 9{,}600$ B.t.u.

38,400 B.t.u.
$38{,}400 \div 130{,}000 = 29.5$ per cent

Hence 29.5 per cent of the total heat of the gasoline goes out in the exhaust in the form of combustible gases, or in other words, the completeness of combustion is $100 - 29.5 = 70.5$.

AVERAGE COMPOSITION OF EXHAUST GAS AND COMPLETENESS OF COMBUSTION

The average percentage of unburned gases found in the exhaust of the various classes of motor vehicles tested was materially higher than was expected in view of the results of somewhat similar although much less extensive road tests reported by previous investigators. Herbert Chase[15] reported in 1914 road tests on 12 passenger cars which showed only one-third of the percentage of carbon monoxide found in the Bureau of Mines tests, although the percentages of carbon dioxide were nearly the same. A comparison of these results are given in Table 6. Ballantyne[16] also states that

> As the result of very numerous analyses of exhaust gases from a great variety of passenger cars, I found that the percentage of carbon monoxide ranged in 1907 from a maximum of 10.3 to a minimum of 0, with an average of 3.5, while in 1908 the maximum was 8.9, the minimum 1.0, and the average 2.7 per cent. It is not too much to say that a gasoline fed car should in respect to the emission of carbon monoxide, be hardly a worse offender than a modern locomotive, the products of combustion of which according to the very full investigation of Brislee, contain in first-class locomotive practice from 0 to 4.2 per cent of carbon monoxide with an average of 1 per cent.

In the Pittsburgh tests only eight out of 44 passenger cars and light trucks showed 3.5 per cent or less of

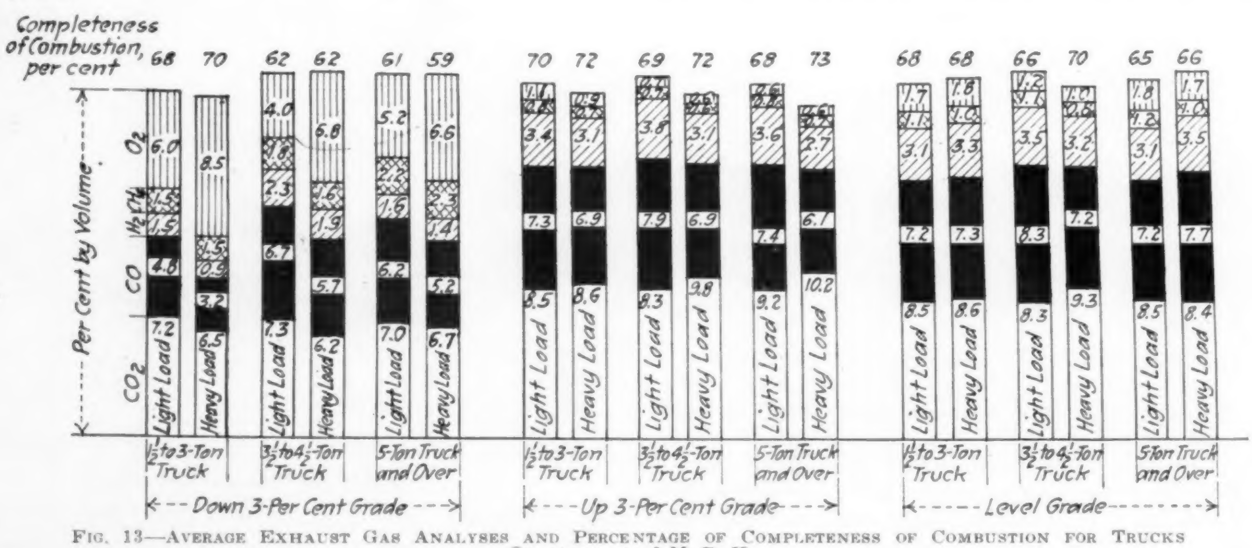


FIG. 13—AVERAGE EXHAUST GAS ANALYSES AND PERCENTAGE OF COMPLETENESS OF COMBUSTION FOR TRUCKS OPERATING AT 6 M. P. H.

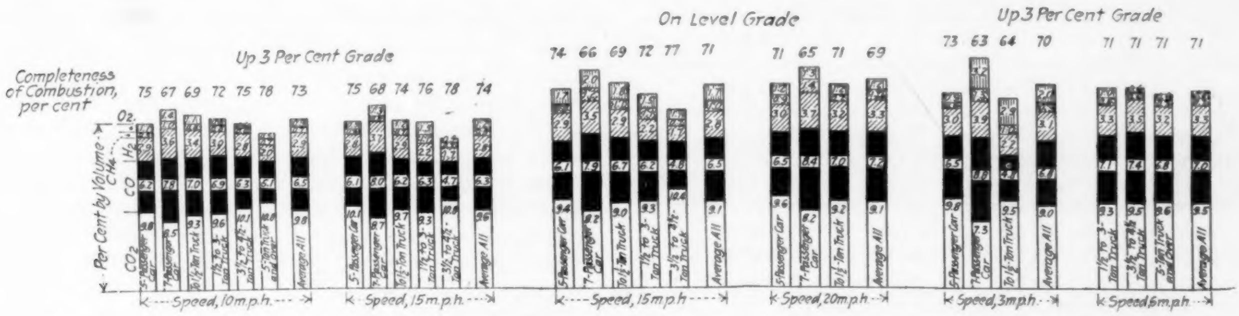


FIG. 14—AVERAGE LIGHT AND FULL-LOAD EXHAUST GAS ANALYSES AND PERCENTAGE OF COMPLETENESS OF COMBUSTION FOR CARS AND TRUCKS OPERATING ON DIFFERENT GRADES AT VARIOUS SPEEDS

carbon monoxide, and the average was 6.5 to 7.0 per cent of carbon monoxide for tests under approximately the same conditions. Undoubtedly the automobile of today has become a much worse offender on the score of discharging carbon monoxide than the coal-burning locomotive.

Figs. 13 and 14 show graphically the average composition of exhaust gas and the completeness of combustion percentage calculated from these analyses for cars and trucks under various operating conditions. Each result is an average of tests on from 12 to 22 cars. Fig. 13 shows a comparison of gas analyses of light and loaded trucks operating at a speed of 6 m.p.h. on various grades. The down-grade tests are characterized by large percentages of oxygen ranging from 4 to 8.5 per cent, and at the same time large proportions of unburned gases in the exhaust. Similar results were obtained on idling tests or whenever the cars were operating on a nearly closed throttle. The least oxygen and the most complete combustion was found on the up-grade tests when the cars were operating with a well-opened throttle. The level-grade tests gave results intermediate between up and down-grade tests. There is also shown a somewhat more complete combustion when the trucks are tested with a load equal to their full rated capacity.

Fig. 14 is a similar graph of average exhaust gas analyses for other operating conditions in which the light and heavy-load tests have been averaged. The greater efficiency with which a truck operates as the speed approaches the maximum for the truck is shown very clearly at the left; as for example in the 10 m.p.h. tests up a 3-per cent grade, the completeness of combustion consistently increases from 69 per cent for light trucks to 78 per cent for heavy 5-ton trucks. The same tendency is shown in the 15 m.p.h. tests. In general the average completeness of combustion ranges from 65 to 78 per cent on level and up-grade tests; the general aver-

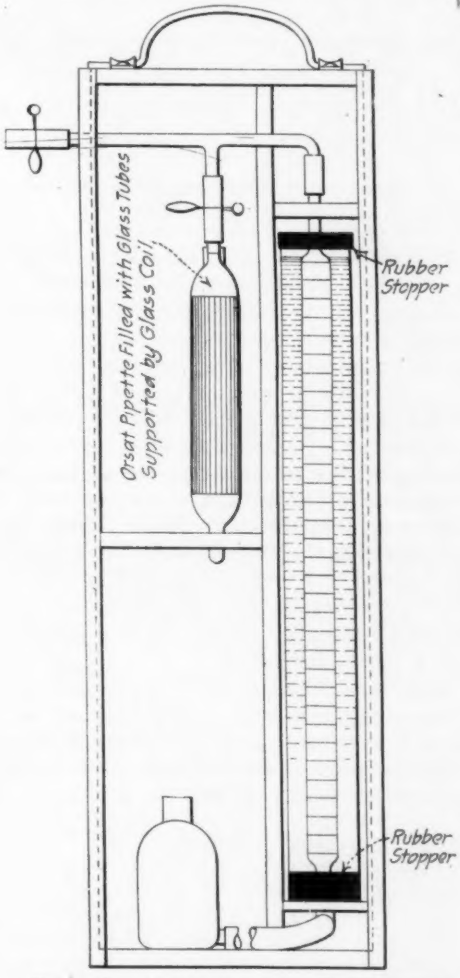


FIG. 15 — APPARATUS FOR DETERMINING CARBON DIOXIDE IN EXHAUST GASES

TABLE 6—COMPARISON OF EXHAUST GAS ANALYSES OF TESTS BY CHASE AND THE BUREAU OF MINES

	Average Exhaust Gas Analysis by Volume, Per Cent					
	Carbon Monoxide			Carbon Dioxide		
	Chase	Bureau of Mines	Difference	Chase	Bureau of Mines	Difference
Car Standing—Engine Idling	2.6	7.1	4.5	8.4	7.9	0.5
Cars Accelerating from Rest to 10 m.p.h. on a level road[17]	1.9	5.5	3.6	10.1	9.5	0.6
Cars Running 10 m.p.h. on a Level Grade	2.3	7.3	5.0	9.7	8.6	1.1
Cars Running 15 m.p.h. on a Level Grade	2.5	6.8	4.3	9.5	9.0	0.5
Average	2.3	6.7	4.4	9.4	8.7	0.7

[17] In the Bureau of Mines tests the speed was 15 m.p.h.

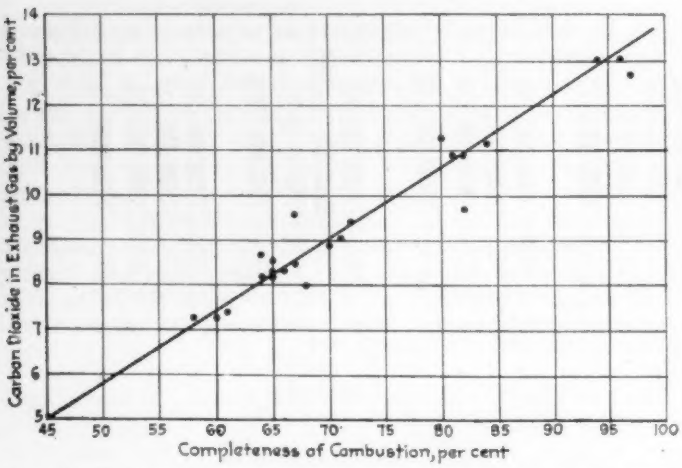


FIG. 16—RELATION BETWEEN THE PERCENTAGES OF CARBON DIOXIDE IN EXHAUST GAS AND THE COMPLETENESS OF COMBUSTION FOR PASSENGER CARS AND LIGHT TRUCKS OPERATING UNDER WINTER CONDITIONS

age for all cars and trucks being approximately 70 per cent.

PERCENTAGE OF CARBON DIOXIDE IN EXHAUST GAS AND COMPLETENESS OF COMBUSTION

The exhaust gas from the gasolines used in the tests should contain from 14 to 15 per cent of carbon dioxide on complete combustion of a theoretically correct mixture with air, without any excess of either gasoline or air. As the combustion becomes less complete the percentage of carbon dioxide decreases proportionally. It is therefore possible to construct curves showing the relation between the percentage of carbon dioxide and the completeness of combustion. These curves can then be used in estimating the completeness of combustion from a carbon dioxide determination with a simplified Orsat apparatus[18] as shown in Fig. 15 in the same manner as the powerplant engineer checks up the efficiency of combustion in a boiler furnace.

Figs. 16, 17 and 18 show such curves constructed from tests of passenger cars and trucks running at 10 and 15 m.p.h. up a 3-per cent grade. Up-grade tests are better for this purpose than level-grade or idling tests on account of the necessity of having a steady load on the engine to minimize fluctuations in the fuel mixture supplied. These curves also serve to show at a glance the wide range of combustion efficiency found in the 101 motor vehicles tested in this investigation. Fig. 18 which represents three classes of trucks from $1\frac{1}{2}$ to 5 tons capacity shows completeness of combustion ranging from 55 to 95 per cent. A little intelligent attention to carbureter adjustment with the help of some carbon dioxide determinations should result in raising the carbon dioxide content to above 10 or 11 per cent, which would produce a saving of at least half of the 30 per cent of the heat in the gasoline now escaping in the exhaust gases as carbon monoxide, hydrogen and hydrocarbons. A change of carbureter adjustment to this extent would not impair the flexibility of operation. It is of course well known that theoretically perfect mixtures with absolutely no unburned gases in the exhaust do not give flexibility of operation on account of the lower velocity of flame propagation. However, good operating characteristics are readily obtained with 12 to 13 per cent of carbon dioxide in the exhaust gas which represents 85 to 90 per cent completeness of combustion.

[18] See Bureau of Mines Bulletin No. 74 entitled Methods of Analyzing Exhaust Gases by G. A. Burrell, p. 73.

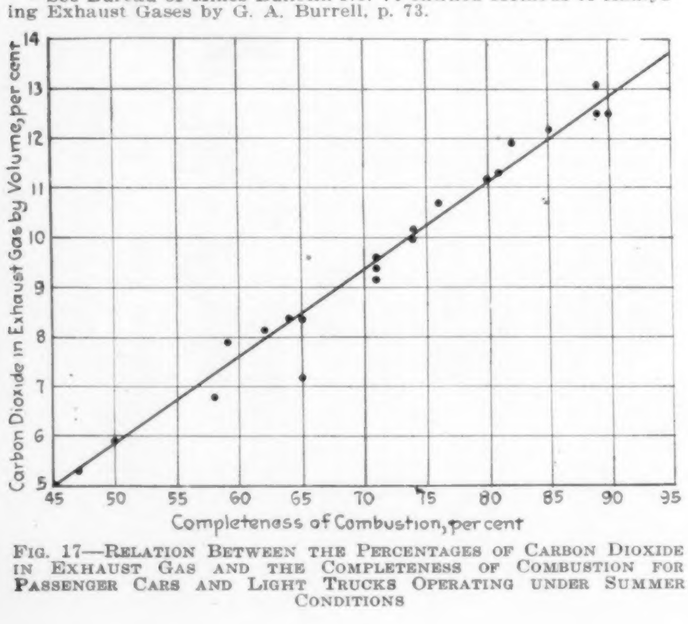


FIG. 17—RELATION BETWEEN THE PERCENTAGES OF CARBON DIOXIDE IN EXHAUST GAS AND THE COMPLETENESS OF COMBUSTION FOR PASSENGER CARS AND LIGHT TRUCKS OPERATING UNDER SUMMER CONDITIONS

SUMMARY

Road tests were conducted at Pittsburgh on 101 passenger cars and trucks of various capacities to determine the amount and composition of the exhaust gas discharged under the various conditions of speeds and grades that may prevail in vehicular tunnels, and especially the particular conditions of the Hudson River Vehicular Tunnel. The results of these tests have shown that

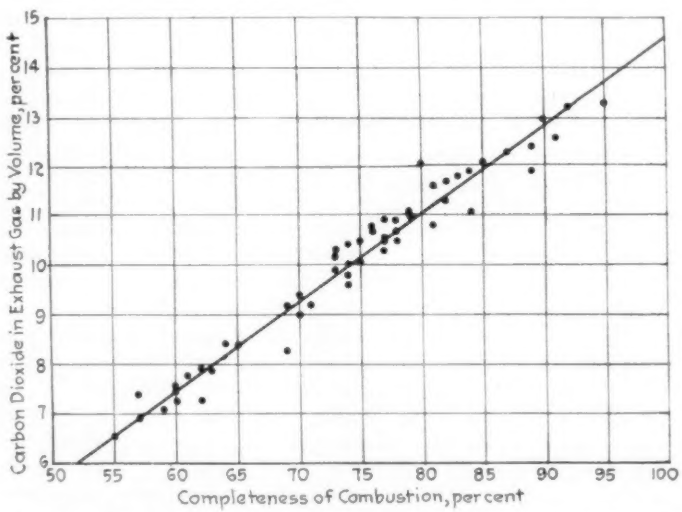


FIG. 18—RELATION BETWEEN THE PERCENTAGES OF CARBON DIOXIDE IN EXHAUST GAS AND THE COMPLETENESS OF COMBUSTION FOR TRUCKS OVER $1\frac{1}{2}$-TONS CAPACITY OPERATING UNDER SUMMER CONDITIONS

(1) Automobile exhaust gas consists of carbon dioxide, carbon monoxide, hydrogen, hydrocarbons, oxygen, nitrogen and water vapor, the relative proportion of these constituents varying greatly in the exhaust from different engines, depending on carbureter adjustment, degree of atomization, compression, etc.
(2) The important constituent of exhaust gas as regards tunnel ventilation is carbon monoxide. Physiological tests on exhaust gas reported by Dr. Yandell Henderson show that the maximum allowable concentration of carbon monoxide in air for 1-hr. exposure is four in 10,000
(3) The percentage of carbon monoxide for the various individual cars varied from 0.5 to 14.0 per cent.

Passenger cars and speed trucks on level grades at 15 and 20 m.p.h. averaging 7.0 per cent and 1½ to 5-ton trucks at 10 m.p.h. averaging 7.3 per cent. Seven to 7.3 per cent of carbon monoxide corresponds to an air-gasoline ratio of 11.8, a slightly richer mixture than is required for developing the maximum power. The maximum power mixture ratio is 12.5; the maximum thermal efficiency mixture ratio is 16.0 and the complete combustion mixture ratio is 15.0

(4) The larger percentages of carbon monoxide are produced when the throttle is nearly closed, as when running down grade or the car standing with the engine idling. The largest quantity of carbon monoxide is produced when the gasoline consumption is greatest, as with cars accelerating or running up grade at maximum speed

(5) Completeness of combustion varies directly as the percentage of carbon dioxide in the exhaust gas and inversely as the percentage of carbon monoxide. For the same carbureter adjustment in a given engine combustion is most complete with the engine operating under full load at its normal speed. However, the completeness of combustion of different cars varies greatly under the same condition of test. The primary factor in causing this difference appears to be the carbureter adjustment. The total range for different cars was 50 to 95 per cent. The average for all cars was about 70 per cent

(6) The combustible gas in the average automobile exhaust from 1 gal. of gasoline contains nearly 30 per cent of the total heat in the original gasoline. Thirty per cent of the 4,000,000,000 gal. of gasoline consumed in 1919 amounts to $400,000,000, with gasoline at 33 cents per gal. Careful carbureter adjustment should result in saving half of this amount

(7) The great majority of motor cars and trucks are operated on rich mixtures suitable for maximum power but very wasteful from the standpoint of gasoline economy

(8) The average motor-car carbureter is set for winter operation and is not changed in the summer, as shown by the higher percentages of carbon monoxide and the richer mixtures found in the summer tests

(9) The public should be impressed with the saving in gasoline resulting from the use of lean mixtures. If the builders of automotive engines would provide for the installation of a small gas sampling tube in the exhaust pipe of engines, especially on trucks, it would tend to introduce the use of carbon dioxide determinations for the control of carbureter and other adjustments. Taxicab and trucking companies could well afford to employ a chemist to make regular control tests. He could save his salary many times over, in cutting down the gasoline consumption

CONFERENCE ON TRAFFIC REGULATION

REPRESENTATIVES of 32 organizations interested in the enactment of a uniform motor vehicle law in the various States, attended the National Conference on Highway Traffic Regulation held in Washington in January. The Society of Automotive Engineers was represented by Major J. M. Ritchie of the Quartermaster Corps.

The Drafting Committee presented a report consisting of a proposed vehicle law based on recommendations sponsored by various organizations. This report was discussed at length. Parts of the proposed law were tentatively agreed upon and other sections referred back to the Drafting Committee.

As a result of the Conference, there was adopted a set of 'principles" on which the proposed uniform law could be based. It was understood that no final action of the Conference should be taken on the law itself but that the law as revised should be submitted to the various organizations interested, any organization being privileged to print such law over its own name if desired but without any mention of the other conferring bodies.

The Principles provide for the administration of the law preferably by a Vehicle Commissioner appointed by the Governor or if necessary by a distinct division of an existing State department. Full power, subject to review by the courts, should be given to refuse, suspend or revoke registrations and operators' licenses.

It is recommended that registration fees should be based on both horsepower and weight except in the case of agricultural vehicles and that operators' licenses should be granted only after the passing of a satisfactory examination. Maximum rates of speed should be fixed at not less than 30 m.p.h. in open country, 20 miles in residential districts and 15 miles in business portions; and a uniform method of hand signaling should be prescribed, denoting the operators' intention of turning, stopping or backing.

Obligatory equipment is described as consisting of the necessary sounding device, suitable brakes and adequate lighting equipment; the lighting specifications to be such as those of the Society of Illuminating Engineers under date of June, 1920, to which the S. A. E. Recommended Practice for Head-Lamp Illumination Operating Requirements as given on page B6, Vol. I, S. A. E. HANDBOOK conform. All trucks should plainly show the allowable gross weight of the vehicle and the load and the seating capacity in the case of those carrying passengers.

Definite wheel, axle and total loads should be established which should be varied according to the kind and width of tires. Rules of the road should be specifically stated, and municipalities given the authority to establish reasonable regulations not inconsistent with the State law.

Among other items covered is the requirement that the owner report to the Vehicle Department all cases of accident, court convictions as the result of accidents and cases of theft. Rules for pedestrians are also suggested.

The Conference expressed its approval of the present efforts to eliminate dangerous grade crossings and also recommended that red lights be used exclusively to denote extreme danger, except in the case of tail-lights; green lights to be used for all other traffic regulation.

The Bureau of Standards was asked to make a study of a uniform system of highway signs, including height, location, color, size and arrangement of letters.

Although no permanent organization was formed and no definite provision made for future meetings, S. J. Williams was elected Secretary of the 1921 National Conference on Highway Traffic Regulation for the purpose of acting as a clearing house for the various organizations represented and of communicating with them when desirable as to possible future conferences.

Passenger-Automobile Body-Designing Problems

By ANDREW F. JOHNSON[1]

ANNUAL MEETING PAPER

THE designer must know first what purpose the body is to serve, and then decide upon its exterior appearance in connection with the car as a whole. The body is only a part of the car and cannot, in the general scheme, be considered separately. After the shape has been decided upon, the designing of bodies to carry passengers is included under three heads; safety, comfort and elegance.

To carry passengers *safely* is the first consideration of the designer and in this matter he meets his first problems. To be safe, the body must be strong in its wood and metal parts. These parts must be joined so that with ordinary usage they will hold together and maintain the shape and stability of the body as it was first constructed. But the body must be kept as light in weight as possible; so the first care of the designer is to produce something strong and at the same time not heavy. To do this he must exercise his best skill as a constructor. Protection from the weather is a necessary feature of the design and doorways of sufficient width to be safe for entering or leaving the car, having no sharp angles or other things to catch and tear clothing must be provided. Harmful drafts of air must be avoided, especially in closed cars, but there must be good ventilation.

After the matter of safety has been carefully attended to, the next consideration is that of comfort. Passengers naturally demand that they shall be able to ride all day in an automobile without being cramped or lamed any more than they would be in the best railroad cars. Comfort in a car depends principally upon the design of the seat. There must be a sufficient height from the floor that the passenger can at least get his heels back far enough so that his knees form a right angle. He cannot ride for long periods of time in comfort without being able to shift his position, and especially the position of his feet and legs. There must be plenty of room for extending the legs to their full length. The seat should not be so wide from front to back that the passenger cannot bend his knees to get his feet back without striking the calves of his legs against the front of the seat while his back is resting against the back of the seat. The seats must be wide enough from side to side to be comfortable for the number of passengers they are designed to carry. If the car is of the closed type, there must be headroom enough to prevent the hats of the passengers when seated from touching the inside of the roof. Nothing is more exasperating to a passenger than to have his hat rubbing the lining of the roof. It is essential that there be an absence of unnecessary noises, such as the rattling of doors, windows and the mechanism of folding seats.

The users of automobiles expect something more than safety and comfort in a car; they demand a certain degree of elegance. Exterior elegance includes correct proportions of the body in connection with the rest of the car, pleasing lines which do not conflict with each other, well fitting and properly hung doors and correct coloring in the painting. Interior elegance calls for pleasing upholstery, which should harmonize as to color with the painting of the car, carefully arranged lighting in closed cars and artistic appointments.

The foregoing are some of the problems met with in designing passenger bodies for automobiles. The designer of special bodies, for customers who furnish their own running-gear, meets problems not encounted by the designer for "production." The opposite of this statement also is true. Of the two, I think that the designer for production sometimes has the harder proposition. For instance, traveling men from different parts of the country bring their ideas in to the home office and many times the opinions expressed vary as to the same part of a car. All the suggestions must be considered, as well as the views of the heads of the firm. From them all, the designer must produce a car that will please the majority of the average buyers of the whole country, and perhaps of the whole world.

One other thing should be borne in mind, especially in designing high-class bodies; it is that after all has been said and done the car is only an adjunct. The car is made to carry people and the people are to be considered first. Therefore, the embellishment of the car, and especially of the upholstery, should be subdued as to color so that the dresses and wraps of the ladies will bring out the full beauty. The car should be a foil for the toilettes of the ladies who ride in it. This is especially true of town cars.

I believe that the "best" car has not been built. I hope to see the time when the mechanical and the body designing engineers in every automobile factory will get together when a new car is to be designed. They should remember that the car about to be built is for the express purpose of carrying passengers, and provide room enough between the dash and the rear so that the passengers can be accommodated. I am glad to be able to say that this is now being done in the best factories. The problems of the body designer are thereby reduced, and the worth of the car as a whole is vastly enhanced without extra expense.

We have become accustomed to look to Europe for the best examples of high-class passenger automobiles, but I believe that in the near future this will not be true. I trust we shall see the time when the European builder of fine cars will say to a prospective customer: "This car is as well built and as well finished as the best American car." With the consummate skill, untiring energy and splendid loyalty of the designers of cars in America, I see no reason why this desire shall not be realized.

[1] Principal, Correspondence School for Automobile Body Makers, Designers and Draftsmen, Gray, Me.

Ignition from the Engineman's Viewpoint

By Capt. George E. A. Hallett,[1] U. S. A.

Metropolitan Section Paper *Illustrated with* Diagrams and Charts

Abstract

IGNITION is discussed in a broad and non-technical way. The definition of the word ignition should be broad enough to include the complete functioning of the ignition apparatus, beginning from the point where mechanical energy is absorbed to generate current and ending with the completion of the working stroke of the engine. The ignition system includes the mechanical drive to the magneto or generator and the task imposed on the system is by no means completed when a spark has passed over the gap of the spark-plug. Ignition means the complete burning of the charge of gas in the cylinder at top dead-center, at the time the working stroke of the piston commences. The means employed to accomplish this result is the ignition system. In the present-day type of gasoline engine a spark produced by high-voltage electricity is almost universally used for ignition. This high-voltage electricity is produced by a transformer. The transformer "steps up" the lower voltage produced from the source of current, which may be permanent magnets or a storage battery. Regardless of the source, the result must be efficient ignition if the maximum power output per gallon of fuel is to be obtained.

The whole program of events in an internal-combustion engine cylinder is then considered as having been slowed down, to assist in grasping the idea of what takes place, and three specific ways to make the charge burn faster are stated. Preignition and detonation are discussed, a statement of the advantages of using two spark-plugs per cylinder and a table showing power results with from one to four spark-plugs being given. Doped fuel is considered and the matter of certain and uncertain ignition is commented upon. Spark-plug tests at McCook Field are described and the mechanical defects in ignition systems enumerated [Printed in the November, 1920, issue of The Journal.]

THE DISCUSSION

A. L. Clayden.—Precisely what does the author mean by 118-lb. compression?

Capt. G. E. A. Hallett.—That is compression measured with an O Kill indicator, while the engine is running at 120 r.p.m. We generally speak of compression ratio, rather than of pressures.

Chairman A. M. Wolf.—We are fortunate in having with us Mr. Young, of the British Thomson-Houston Co. I believe many are acquainted with him or at least have read his book on magneto ignition.

Arthur P. Young.—Captain Hallett has referred several times to the necessity of having a "strong" spark. Exactly what does he mean by a "strong" spark? What is the particular characteristic that distinguishes what he calls a "strong" spark from one which he labels "weak"?

Captain Hallett.—I avoid that part of the discussion; I am extremely neutral and desire to keep the discussion away from battery versus magneto arguments.

Mr. Young.—I rather suspect that Captain Hallett has in mind the heat energy liberated in the discharge; that is, the joules per spark. If such be the case, it would seem that he has been advocating strongly a spark having those characteristics which are present in a magneto discharge, to meet the increasingly severe conditions that are likely to be imposed in the future by airplane engines designed for super-compressions and fed with fuel of low quality. The question of magneto versus battery ignition is a highly controversial one, and Captain Hallett wisely avoided all reference to it. I, therefore, could hardly have the temerity to raise this discussion, in the very home of battery ignition, but I cannot avoid making general observations on the results of Captain Hallett's experience and experiments with airplane-engine ignition.

In considering the process of ignition it is well to analyze exactly what happens when a high-tension spark is initiated. At the moment of separation of the contacts which control the primary circuit, and I am now dealing in a general way with either form of spark generator, the voltage induced in the secondary winding begins to rise from zero at a very rapid rate, in consequence of the sudden destruction, and reversal, with a magneto, of the magnetic field associated with the primary and linked with the secondary. We can look upon the complete high-tension circuit comprising secondary, high-tension lead and spark-plug, as possessing a certain amount of distributed capacity; so, in effect, we have linked across the spark-plug electrodes an imaginary condenser having a capacity equal to the distributed capacity in the high-tension circuit.

The secondary voltage grows at a phenomenally rapid rate, which is of the order of 300,000,000 volts per sec. at the moment of separation of the contacts in a high-tension magneto. As the secondary voltage increases in value, the imaginary condenser becomes charged and the voltage between its ends, and therefore between the spark-plug electrodes, rises with this extraordinary rapidity until it reaches the value E, which is the sparking voltage of the gap. At the moment this happens a spark occurs, and the imaginary condenser in question discharges itself across the gap with very great rapidity, giving in this first "bright-line" discharge an amount of energy equal to $\frac{1}{2}CE^2$, where C is the distributed capacity in secondary circuit in farads. After the first bright-line, or "condenser," discharge, comes a spark which persists for a relatively long period, this portion of the spark containing the electromagnetic energy that has been stored in the primary winding. It gives what is called the flamy part of the discharge, and it is this part which contains the greater portion of the heat energy liberated in the discharge. The two fundamental components of an ignition spark can be visibly observed on a rotary test-gap in which the discharge is spread over an arc of a circle by a rotating electrode. In this manner

[1] M. S. A. E.—Chief of powerplant section, engineering division, Air Service, Dayton, Ohio.

the first discharge can be observed as a single bright line, and the other portion of the spark is seen as a colored flame spread over a considerable angle. The duration of the first bright-line discharge is probably considerably less than 1/100,000 sec. Recent research has demonstrated that under ideal conditions this is the component of the spark which causes ignition. What follows is of little value from a purely ignition standpoint.

The fundamental distinction between a magneto spark and the spark generated by a battery-coil system is that, in the latter case, the flamy portion of the spark is not so highly developed. This means that at cranking speed and above, the heat energy in a magneto spark is considerably greater than that liberated by the spark generated by the other system. If, as I have already stated, the first portion of the spark is responsible for ignition, it might be assumed hastily that there is no advantage in having a flamy portion which persists for a considerable period of time. Viewing the problem from this angle, one could rightly conclude that it is desirable to make the first spark component as pronounced as possible; in other words, E must be as large as possible, the distributed capacity being controlled mainly by the characteristics of the high-tension circuit external to the spark generator. As a matter of fact, the view is now generally held in England that, in designing any form of spark generator, it is desirable to obtain a secondary-voltage wave-front which is as steep as possible. That is, the rate of voltage rise in the secondary at the "break" should be made exceedingly high and, other things being equal, this is a factor which determines the capabilities of a machine as a spark generator.

But we still have to consider the question of spark energy; that is, the efficacy, or otherwise, of the flamy portion of the spark. Although this may be of no value under ideal conditions, it does not follow that it is not desirable to generate a flamy component because, in practice, the conditions are frequently far from ideal and it is these adverse conditions which really determine what the characteristics of a spark should be. When everything is cold at starting, for example, the mixture enters the cylinder in the form of a mist, and it is easy to picture gasoline globules of considerable diameter floating about in the airstream that passes across the spark-plug electrodes. It is reasonable to suppose that under these conditions the heat energy liberated by the spark serves a useful purpose in vaporizing some of the globules and thus producing in the path of the spark a localized mixture of gas and air which approximates the ideal. A simple calculation shows that a spark containing only 0.03 joule of energy is capable of vaporizing 10 globules of gasoline each of which is 0.01 in. in diameter. Almost any magneto will generate a spark which does not contain less than this amount of heat energy at a cranking speed of about 100 r.p.m.

To obtain easy starting, therefore, one can safely assume, I think, that it is an advantage to generate a spark which contains a considerable amount of heat energy. This is becoming increasingly true now that the quality of the fuel available is degenerating rapidly. The view is frequently expressed that the magneto is obviously at a disadvantage as compared with the other ignition system, at starting, for the reason that in the latter case the best spark is produced at zero speed. While this latter statement is perfectly true, the argument is not quite sound because, in actual practice, we are concerned not with zero speed, but with the cranking speed of say 100 r.p.m. At this speed a well designed magneto gives a spark which contains certainly not less heat energy than that liberated by the spark of the other system. In the latter case the sudden drop in the battery voltage produces an enormous reduction in the heat energy of the spark which is approximately proportional to the *square* of this voltage. The spark-energy curves given in Fig. 1 are of interest in this connection.

Considering the normal running condition, it can be rightly conceded, I think, that with the engine thoroughly warm and the carbureter functioning in a suitable manner, satisfactory ignition will occur so long as there is a spark, and that the heat energy of the spark is not of paramount importance. We are faced here with a condition where the first component of the spark is the master of the situation. Admitting all this, however, what are the factors which determine whether or not a spark shall occur? Fundamentally, the answer is simple. A spark will result if the voltage rise across the spark-plug electrodes reaches the sparking voltage of the gap. But under working conditions there are two main factors operating which tend to retard the rate at which the secondary voltage rises, thereby tending to prevent the sparking voltage being reached and in consequence the occurrence of a spark. These factors are (*a*) excessive distributed capacity in the high-tension cables and (*b*) excessive leakage in the high-tension circuit, more particularly in the spark-plug itself.

To guard against undue slowing up of the rate of voltage rise, it is necessary to design the spark generator to liberate in the spark a considerable amount of heat energy and, apart from the question of ignition per se, the spark generator which gives the spark of greatest heat energy will, other things being equal, be best able to meet the adverse conditions that are imposed by the two factors (*a*) and (*b*). I have in mind the case of a certain airplane engine where it was necessary to use braided high-tension cables to eliminate wireless interference. The distributed capacity was thereby increased to such an extent that, at high speeds, missing occurred simply because the voltage induced in the secondary was so retarded in its growth that it did not reach the sparking voltage of the spark-plug gaps. This occurred with a magneto. With unbraided cables, giving a much lower distributed capacity, the ignition was perfect.

I was extremely interested in the supercharger designed by Dr. Moss of the General Electric Co., referred to by Captain Hallett, because it so happened that it was my privilege to be associated with Dr. Moss some 12 years ago in this country. The use of a supercharger raises an interesting point in connection with the design of spark generators; that is, the question of the safety spark-gap. In the ordinary way the sparking voltage of the safety-gap decreases with increase in altitude almost in proportion to the decrease in air density, but this is not detrimental because the sparking voltage of the spark-plug gaps falls off in much the same way, thus insuring that the sparking voltage of the spark-plug gap is always less than the sparking voltage of the safety-gap. If a supercharger is used, this relationship will no longer hold and, at a certain altitude, the plug voltage will become equal to the safety spark-gap voltage. Missing will then occur, and this will become progressively worse with any increase in altitude. The logical way of obviating this difficulty would seem to be to enclose the safety spark-gap in a small glass tube filled with some inert gas, so that its sparking voltage is unaffected by atmospheric conditions. This arrangement will give a constant sparking voltage at all altitudes.

Dr. R. H. Cunningham:—Mr. Young has expressed my ideas in a general way in regard to the action of the magneto spark. Captain Hallett mentioned the increase in horsepower in connection with the use of two simultaneous sparks, running up even as far as four sparks. About 10 years ago, being connected with one of the largest American magneto companies, I brought out a two-spark system in which the energy of the spark-coil could be utilized on either the intake plugs or the exhaust plugs, or on both at once. In using these twin sparks, ordinarily we have to take certain electrical precautions. Generally, the frame of the automobile acts as a condenser of fair capacity and, unless certain precautions are taken in the setting of the spark-plug points, if one measures the time interval between the two sparks it will often be found that one spark occurs slightly later than the other. At that time I constructed an apparatus whereby we could measure the occurrence of the sparks within 1/100,000 sec., and it was very evident that under certain conditions these sparks could vary. Some very curious results occurred in certain kinds of engines with the gasoline that was then in common use. In some engines it was found that, instead of getting increased power with the two sparks, we got considerably less power. The two sparks apparently would cause an instantaneous or an almost instantaneous explosion of the charge, seemingly so quick that the piston would not respond properly to this sudden explosion, the gas being too suddenly and entirely consumed and not burned as under ordinary conditions.

Then I built a four-spark apparatus in which two magnetos were synchronized, but they were actuated by one circuit breaker. In the particular engine to which this was applied there was no increase in the power because of using four spark-plugs instead of two. In fact, in that engine, a single-spark magneto that had about 10 deg. advance greater than the ordinary single-spark magneto was capable of giving the same amount of power as with two sparks. So, when these double-spark magnetos were applied to various motor boats, having engines of moderate speed or, comparatively speaking, slow-speed engines, the two sparks were extremely detrimental. On high-speed racing cars, however, having very high piston speeds, the two sparks were advantageous. Some years later, when using a magneto which would allow an 80-deg. advance, this magneto giving an extremely hot-arc spark on a very long-stroke engine, it would do about what the two-spark ignition would do. The point is that if we increase the number of sparks, we are very liable at the low speeds to get too rapid firing of the gas. In that way we get a variety of "knock" and the piston speed falls off. To avoid this we had to increase the gasoline consumption by making the mixture richer so as to burn somewhat more slowly, thus compensating for the sudden detonating type of firing. If carbureters can be arranged so that we can adjust for these difficulties, the use of ignition apparatus with the ordinary degrees of advance will probably result in an increase in power if two sparks are used.

In reference to spark strength, hot sparks and the like, one great difficulty is to find a method of measuring exactly the maximum strength of the current in a spark. The heat depends upon the current strength and it is really a very difficult thing to say exactly how many milliamperes exist in a spark from an induction coil or from a magneto. Such currents are very rapid and usually are beyond the capacity of most registration apparatus. Merely because there is a spark across the spark-plug, it does not necessarily follow that with each different variety of ignition apparatus the character of that spark will be the same. There may be a single spark or intermittent sparks. As mentioned by Mr. Young the rise in voltage by which the capacity of the circuit, secondary winding, the spark-plugs and the cables, is charged, may be enough to jump the gap, forming just one spark, or a few uni-directional intermittent sparks, or even several damped oscillatory sparks. The charge may jump the gap and, after the occurrence of one or more oscillations, a small arc form which may or may not imitate a large or a small explosion accompanied or not accompanied by a knock. My experience with various ignition systems has been that when the voltage is sufficient to produce an arc concomitant with the first spark,

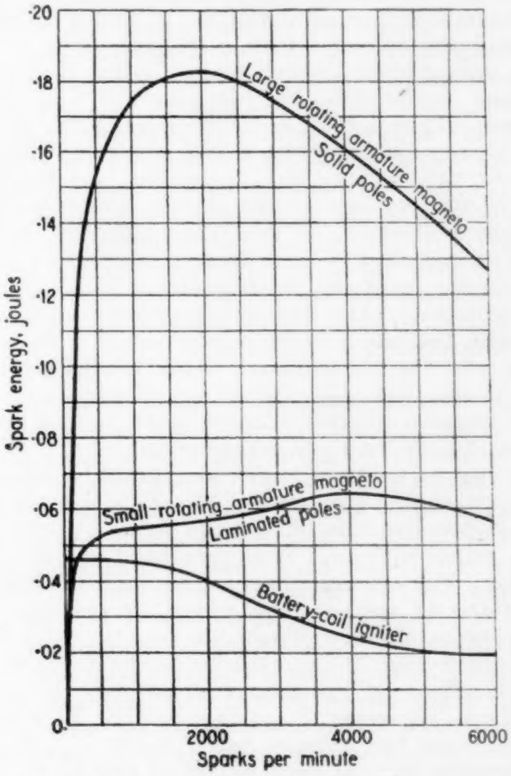


Fig. 1—Spark-Energy Curves of Different Ignition Systems

we get the best results. The weakest mixtures can be used then, and the gasoline consumption is thus diminished considerably. As already stated, there are varieties of apparatus in which the rises of voltage occur as follows: The electrostatic charge jumps the gap, the voltage drops almost instantly and that spark ceases. The voltage again rises and the first spark is followed by one or two feebler sparks. With this type of "spark," knock will often be established. It is difficult to say to just what the effect is attributable.

I think it was Dr. Watson who found out that, after an engine heated up and got running, the intensity of the spark could be reduced very greatly. My own experience agrees with his. I pointed that out, about 1915, at the Indianapolis meeting. But it is at the beginning, when the engine is cold, when poor gasoline and low temperatures prevent the vaporization of the gasoline, that the arc spark is desirable. When there is only a kind of a fog or mist in the cylinders, heat must be generated at the spark-plug so as to produce real gas; this makes the heat valuable. For some time past I have

been experimenting with a magneto in which the energy is concentrated so as to produce a maximum primary voltage and a secondary current which lasts a very small proportion of the time of the half cycle but which is intense enough and lasts sufficiently long to ignite almost any fuel, even raw kerosene. So, I think the hotter the spark is, particularly when in the form of an arc, the better able we are to fire and utilize present-day fuels.

A MEMBER:—I think the previous discussion has shown the state of science at present in the ignition field. It is that we really do not know very much as yet. I will relate some experiences I had some time ago in connection with experiments with a small stationary engine. The problem was just what ignition system could be adopted for the then state of the art. I had a small stationary one-cylinder engine the cylinders of which were some 4 or 5 in. in diameter. I first used four dry-cells and the coil and took a diagram with a regular steam indicator of English make. After that I ignited the same engine with the hot tube and took the same diagram. Then I took a diagram using the make-and-break system, which gives a low, emphatic, long spark. Bosch brought out one of his magnetos just at that time. I rigged one up, ignited the engine with this magneto, and took a diagram. When these diagrams were compared, we saw that if there was an increase in power, it would be in favor of the hot-tube method. But, with good carburetion, the diagram was almost absolutely the same with the four-cell dry-battery spark with the small coil, as with the big make-and-break emphatic spark. It seems to me that, with conditions of carburetion, it is almost immaterial what kind of spark is used to ignite the mixture. With a cold engine or imperfect carburetion conditions, the diagram might be slightly larger, if four, five, or six spark-plugs were used. This is a much more intricate problem than it appears to be. Experimentation is rather difficult. It is very hard to get an exact indicator. The same engine must be operated with different systems of ignition and with different locations of spark-plug to obtain comparative results. The location of the spark-plug in the cylinder seems to have a considerable effect on the output of engines of the same dimensions. It seems to me that neither on top of the inlet nor near the exhaust valve is the right location. This problem has not been solved so far as my experience goes.

Regarding the unexplained phenomenon of the auxiliary gap, I am experimenting with a Ford engine on which I have been able to measure the output. It seems that the auxiliary spark-gap gives a considerably greater economy. I have not been able to determine what the reason is, but the fact remains that if the same spark-plugs and the same ignition system are installed on the same engine, the carburetion can be cut down and a leaner mixture can be ignited with an auxiliary spark-gap than without one. The size of the spark-gap itself seems to be related in some degree to the engine compression. Just what the relation is I have not been able to determine.

M. E. TOEPEL:—I experiment with engines that are used in every-day practice, and we encounter some very knotty ignition problems. I think that the composition of the spark-plug electrode is one of the things that needs the greatest revision at present. The ordinary 98 per cent nickel electrode used today is not sufficient; a metal is required that can withstand more heat than that can. I read recently that in England they are coming to tungsten. I agree with what Captain Hallett said in regard to cavity; in other words, we should avoid any more cavity in a spark-plug than is actually necessary.

Captain Hallett said that in setting fire to a brush pile it is better to ignite it completely around the circle. If the wind is blowing in a certain direction, that is not necessary; it can be set on fire on three sides and the natural draft will take care of the rest of it. The statement that the propagation of flame is like the effect of throwing a stone into water, is incorrect. That applies to the early and better type of fuel. Turbulence is required for the present type of fuel. It has been said that we need more spark heat. Whenever we have applied more spark heat, we have found that the electrodes of spark-plugs would not last very long. Consequently, if the manufacturers give us ignition having very high spark heat, the present spark-plugs will need to be readjusted almost every day.

Concerning the mixture itself and the location of the spark-plug, I think we have not determined the correct location. This has a bearing on the heating of the valves. Under ordinary conditions we cannot change the spark-plug location easily on an engine.

In practical every-day engines, not including high-powered airplane engines, we find that ordinary two-spark ignition does not increase the power; but it gives smoother running and a great saving in gasoline, irrespective of where the spark-plugs are placed. Even if we place the spark-plug directly over the exhaust valve, we find it runs much cooler when idling and lowers the gasoline consumption, but it develops lower power.

How far has doped fuel progressed? Will it be made in commercial quantities? Can we experimenters obtain it? Mr. Kettering mentioned anilin and other chemicals of similar nature. Are they procurable at present?

CAPTAIN HALLETT:—At present the General Motors Research Corporation is working on many different compounds. They have used one called anilin oil and another called xylidin. I think neither is obtainable in the ordinary sense, but I believe the organization named would provide some for experimental purposes. I know they are planning to use cheaper compounds and are finding ways to make these in much larger quantities. They are arranging also for very complete distribution and those compounds will be available eventually. One way to start such work is to use benzol in the fuel; 20 per cent of benzol will take the knock out of an ordinary engine.

MR. TOEPEL:—I do not know whether every engine will rise to 160 lb. per sq. in. compression pressure, but I think some of them can make use of higher compression.

A. R. MOSLER:—How are self-ignition and preignition defined?

CAPTAIN HALLETT:—I know of no difference between premature ignition and self-ignition. I call them both preignition. I only tried to differentiate between that phenomenon and the phenomenon we call knocking, in which case merely detonation of the remaining portion of the charge exists. I feel that "pre" or early ignition and self-ignition are the same.

MR. MOSLER:—About 20 years ago, when making experiments with carbureters, we used a very lean mixture and obtained extremely high speeds with no power at all. We noticed also at that time what we did not recognize was detonation of the gases. The most essential feature in spark-plug construction to prevent preignition is that the plug shall be absolutely gas-tight.

WILLIAM HASSELKUS:—Has any particular difference been found in testing engines between wiring one mag-

neto entirely to the exhaust side and one to the inlet side, rather than wiring to each cylinder bank? If wired to the exhaust sides and inlet sides through each magneto, has any particular difference been found in setting the exhaust side, say about 3 deg. ahead?

GEORGE J. MEAD:—There was a difference, but it was very slight. As I remember it, the magnetos attached to the exhaust plugs were the ones having a slight advance over those on the intake side, to get the best power.

CAPTAIN HALLETT:—It is not the present brake mean effective pressures resulting from present-day compressions that force us to design engines as strongly as we do, but rather the uncalculated strains imposed by occasional preignitions. The use of 160 lb. per sq. in. compression pressure, together with fuel which will not preignite would, in my opinion, cause no distress in present engines.

CHAIRMAN WOLF:—In covering the subject of ignition in its broad sense, this session would not be complete without discussing it insofar as it applies to Diesel engines. Therefore, I ask that someone tell us about "ignition" as applied to these engines.

Perhaps there is no difference in spark strength with magneto and with battery ignition, but I am inclined to believe there is. Captain Hallett and I ran some tests at McCook Field with a Liberty engine equipped with both ignitions. One part of these tests was an idling run of 1 hr., during which we used large amounts of oil which the engine utilized at full throttle, the additional oil being supplied through the air intake to the carbureters. The spark-plugs looked cleaner after they had been run with the battery system than when run with the magnetos. The reason for this we could not explain. I have since wondered if this condition had some relation to the strength of the spark. For example, if we contend that the battery-ignition spark is not so hot as the spark from the magneto, perhaps the plugs would be cooler and the oil would not carbonize on them; whereas, the arcing spark of the magneto possibly carbonized the points.

V. W. PAGÉ:—What of the automobile engine designer who must design parts that will withstand the brake mean effective pressure resulting from 160 lb. per sq. in. compression pressure, and keep the weight and the cost down?

ELMER A. SPERRY:—Diesel engines do not use spark-plugs. They get ignition by high temperatures and then injecting the fuel. We have an idea that this is the coming way to obtain ignition. Diesel engines run under a tremendous handicap as regards compression space; they have chilled walls and very low fuel content, but they show excellent economy owing to the high compression and high temperatures. We believe that, although those engines are handicapped by the extra super-compressed air necessary to energize the oil as it comes in, when we eliminate this as it seems we can and have a large-sized clearance space on top of the piston, possibly those two things together would develop the Diesel cycle and make it light enough so that we can employ it in regular automotive work. We are making steady progress toward this end. With the Diesel cycle available, we would not be tied down to gasoline and would be relieved at once from many difficulties, especially those causing the negative loop on the indicator card. All explosion engines are handicapped in the matter of very close adjustment of mixture. When the mixture is right, we must do all further manipulating entirely with the throttle. Engines in actual service conditions are gasping for breath probably 95 per cent of the time; Nixon says 99 per cent. Of the small power that we then get, when the compression curve starts at sub-atmospheric pressure, a large part of that power has to be applied immediately to supply power to the negative side of the card and that power never becomes positive. Some of those things should be avoided.

The sum total of following the Otto-cycle explosive-mixture engine is that we are handling about 5 per cent thermal efficiency to the rear axle. I am a most thorough believer in the statements of Mr. Kettering that it will be common practice presently to deliver between 25 and 40 per cent thermal efficiency to the rear axle. We must save fuel; if, in saving quantity, we can do away also with the limitations in quality, those two things will be beneficial to automotive engineering.

WILLIAM C. BRINTON, JR.:—The need of a stronger spark to start the engine with has been mentioned. That is a very good argument for battery ignition because, if there is any class of ignition with which an excessively strong spark is produced at starting it is the battery ignition. We have been told that the great advantage of the magneto is that at high speed it has a very hot spark. I would like to have it proved that the heat of the spark of a magneto or one from a battery system is what accomplishes the desired result. With the make-and-break system, we have the temperature of the electric arc. With the jump-spark system of today it is practically impossible to prove that it is heat that accomplishes the result.

The Bureau of Steam Engineering received a report from the British Admiralty in January, 1918. They have conducted a test over a period of two years to determine what properties of the spark produced satisfactory ignition and in their conclusion they stated that they had not been able to find what produced satisfactory ignition but that they had proved that it was not heat.

The Seeley high-frequency system worked out rather disastrously on several passenger cars but under good conditions the system did work well. The high-frequency current objects to turning corners on such a system and under certain conditions nothing is obtained at the plug. In this system the current was purely a condenser discharge which is known as an ampereless discharge.

In regard to firing one or more plugs per cylinder, the advantage depends largely upon the shape of the cylinders. In a T-head engine, firing one plug over the intake, the magneto develops a given brake-horsepower. Firing two plugs simultaneously, one over the intake and one over the exhaust, an increase of 35 per cent in horsepower was shown. With L-head engines at low speeds we find very little difference. An engine on which we tested a plug over the exhaust was timed 3 deg. earlier than that over the intake and there was an increase of about 5 per cent in horsepower. This, however, is not always the case.

A. F. WAGNER:—Increased horsepower has been discussed, but I believe we are trying to get economy. With that increased horsepower, was the quantity of gas decreased? I have heard nothing about economy with increased horsepower.

CAPTAIN HALLETT:—In aviation engines we have always had better economy with the use of more spark-plugs. It has, however, been necessary to adjust the spark-advance differently with each number of spark-plugs. Did Doctor Cunningham adjust the spark-advance differently and in such positions as to get the best results with each different number of spark-plugs used?

DR. CUNNINGHAM:—The adjustments were made to get the best results out of the engines. We also could run the magneto very much further advanced than is ordinarily the case.

F. W. ANDREW:—Perhaps the effect of two spark-plugs at different speeds is not quite clear. I think the effect in relation to the shape of the cylinder has not been brought out. I think that nobody has made experiments to find out why the spark-plugs will give more power with the T-head engine at certain speeds. When we reach racing speeds, I do not doubt that the two spark-plugs will give better efficiency and economy also; but with truck engines, that do not ordinarily run more than 1000 r.p.m. and carry their heaviest loads at 500 r.p.m., we have a different problem. Rapid flame spread at this speed is not desirable.

Mr. Young spoke about what happens to the safety-gap when the Moss supercharger is used at great altitudes. I think there is no safety-gap in the ignition system that was used with that supercharger; that is cared for in another manner.

Regarding the doping of fuel, will this be done with present-day gasoline, thereby failing to increase our supply of gasoline, or with some such oil as fuel oil? What we are all interested in today is to increase the amount of gasoline available. I think we will not accomplish that by "doping." I think that is working along the wrong track. If we can dope a lower grade of fuel than gasoline, we will arrive somewhere. Is a lower grade of oil than the present grade of gasoline being doped experimentally now?

CAPTAIN HALLETT:—It is my understanding that Mr. Kettering hopes to dope fuel oil, as you suggest, and in that way make it possible to use fuel oil with compressions higher than those now used with gasoline; in that case we would have fairly clean burning in the cylinders due to the higher compression. I believe Mr. Kettering feels that when the distribution of "dope" is an accomplished fact and it is really available all over the country, new automotive engines and old ones already in service can be equipped gradually with much higher-compression pistons, in that way greatly improving the economy and, by allowing us to use lower grade fuel, greatly stretching the fuel supply.

As regards the supply of fuel, it seems that not enough benzol is available so that a mixture of 20 per cent benzol and 80 per cent gasoline can be used, thus eliminating knocking, or a 50 per cent benzol mixture, thus permitting higher compressions. Alcohol, I believe, would be a good anti-knock compound; but it will not mix with gasoline unless benzol also is present. It seems that while we shall be able to spread the supply of gasoline by doping it with alcohol and benzol, we also must stretch it by doping it with anilin oils and the other compounds that Mr. Kettering is developing.

FIG. 2—THE SPARK-PLUG IN THE SPARK-GAP

I hardly meant to recommend the use of compressions as high as 160 lb. per sq. in. in truck engines, but was trying more to point out to the ignition manufacturers that very high compressions and severe conditions are coming.

MR. BRINTON:—Do your experiments show whether it is better to have the spark at the top of the combustion-chamber or further down?

CAPTAIN HALLETT:—Dr. Dickinson has done work along that line. It is my understanding that he attained very favorable results by extending the spark-plug electrodes down into the center of the combustion-chamber. I believe he did this by using an ordinary spark-plug and making very long and very slender electrodes which would be chilled during the intake stroke so that they would not cause preignition.

MR. BRINTON:—We had trouble in doing that because by using a long plug with high compression preignition is bound to occur in practice.

CAPTAIN HALLETT:—I believe you are right. I think it would be very difficult to cool electrodes there, but I was assured that in this experiment of the Bureau of Standards they succeeded in keeping the electrodes cooled.

A. D. T. LIBBY:—I find myself heartily in accord with many things that Captain Hallett has said. I think he hit the keynote, so far as ignition is concerned, when he said that the ignition should be capable of burning the gas very rapidly. Whether ignition effect is like that of a stone thrown into a pond, or like a torch applied around

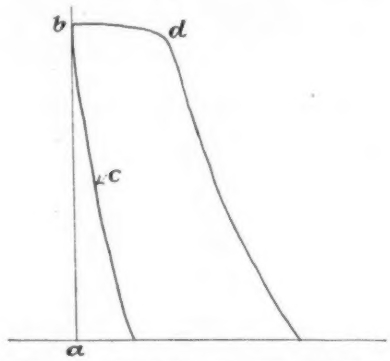


FIG. 3 — DIAGRAM OF THE VOLTAGE WAVE FORM IN AN IGNITION SYSTEM

a brush pile, makes little difference; the point is that it must burn the gas very rapidly. Captain Hallett's idea of having a superfluous amount of heat in the spark appears to me to be the logical thing.

We have many things to contend with in an ignition system. The problem is not entirely that of the breaking down or jumping of the spark-plug gap. We must take care of the leakage in the various parts of the ignition system, such as the cables and the distributor, and of surface leakage in the spark-plugs themselves. The plugs become fouled with oil or moisture and the ignition system must have capacity enough to produce real ignition under such conditions.

Fig. 2 represents the spark-gap in the spark-plug. The system, running back to the distributor, must supply energy enough to charge the cable, take care of the leakage losses in the spark-plug, and finally get across the gap with sufficient energy to ignite the charge. When the charge is just right for rapid combustion, that is when the carbureter is working just right and there is a good resultant mixture, not much energy is required to fire the charge. But there are many times

when those conditions do not prevail; therefore we must have an ignition system that is capable of meeting all these circumstances in all kinds of weather.

Suppose we have an ignition system in which the initial wave-form has substantially a vertical rise, as shown in Fig. 3. The instant the spark-plugs become charged to the potential illustrated by the line *ab*, that is, the charging up of the cables to the point where the current is ready to jump the spark-plug gap shown in Fig. 2, if the spark immediately drops off in the manner shown at *c*, we have nothing to heat the gas around the vicinity of the plug at the instant of discharge, provided the curve of the ignition is of the form shown at *c*. It is my contention, therefore, and I have gathered from Captain Hallett's paper that it is his viewpoint, that the spark, instead of dropping off and back to the zero line at once, should remain at or near its maximum for a certain length of time, as indicated at *d* in Fig. 3, and then drop off. With a spark of the character indicated at *d* in Fig. 3, we stand more chance of burning all the poor mixtures. With a mixture that is extremely rich, particularly in cold weather, we encounter globules that have not really been vaporized.. If globules of fuel are in the vicinity of the spark-plug gap and we have a spark carrying a reserve value of heat, the heat spreads in the manner shown in Fig. 2, the spark shooting across the gap, instantly followed by what we term "whiskers," indicated by the shaded portions. which reach out to engage the mixture that is in close proximity to the spark-plug gap.

With such a spreading of the spark, we have much more chance of firing the mixture, because of the excess of heat at the instant of jumping. My view is that while this initial rise *ab*, in Fig. 3, must be very rapid, it should be followed by a definite amount of heat, indicated by *d*, to get the most rapid flame propagation.

A question was asked as to what is being done in the way of investigating the heat of sparks. The two upper curves of Fig. 4 illustrate a magneto on which I recently measured the heat value of the sparks; it is our regular everyday product and we consider it an excellent machine, but the magneto which gave the bottom curve has three times as much heat in the spark.

VICTOR GREIFF:—About the best that we can boast of at present is a spirit of earnest inquiry. We are doing all we can to cooperate with engine designers, engine builders, engine testers and spark-plug locaters, in this matter. In the meantime, if we have a spark which has that initial static discharge referred to by Mr. Young; that has, after that, a discharge of inductive energy, i.e. electro-kinetic energy; and that then has an electro-dynamic generated arc, which is the nature of the spark given by the old-fashioned magneto, we certainly have all the elements that can possibly be provided to do everything that can be expected of the spark. We have followed the work of Mr. Young with great interest, that of Mr. Morgan, who has, I believe, worked along similar lines, and also of a number of British investigators of

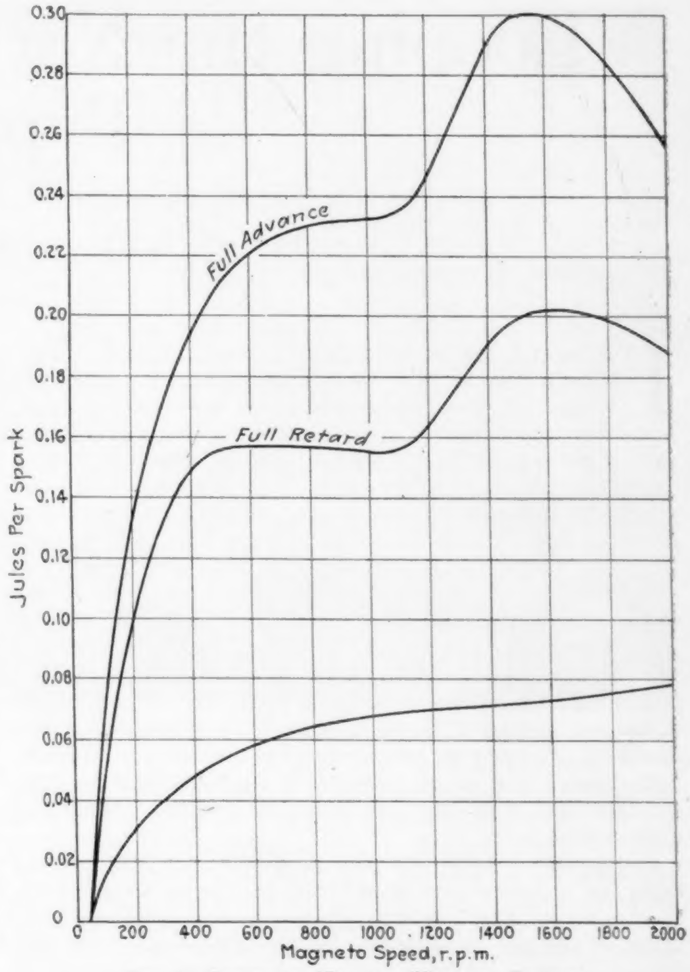


FIG. 4—CURVES OF HEAT IN MAGNETO SPARKS

great skill and insight who are the leaders in ignition research today.

A MEMBER:—We must break down the tendency for the spark not to jump through the compression. Captain Hallett says that if we raise the compression we must raise the voltage to penetrate it. Next, we must put the heat in after we have broken down that compression. So far as the spark-plug is concerned, when spark-plugs can withstand extreme heat, we will provide whatever heat is wanted.

MR. PAGÉ:—A company that makes both magnetos and spark-plugs has representatives present. What steps are they taking to keep their spark-plug construction up to the heat of their magneto spark?

E. A. ROBERTSON:—We think that the spark-plug we make will hold down any ignition system there is at present. Spark-plug engineers have been experimenting for years with high-compression engines but, so far as I know, there is no spark-plug yet that is satisfactory for use in engines with the high compressions Captain Hallett speaks of.

Looping the North Atlantic in the Typhoon

By William Washburn Nutting[1]

Motorboat Meeting Address

Illustrated With Photographs

It is gratifying to feel that I am still eligible in such a gathering as this. After the harrowing press accounts of Typhoon's cruise, I felt that I might have lost my standing as an amateur sailor and skidded into a class with Steve Brodie and the chap who went over Niagara Falls in a barrel. Not that there was any particular purpose in the cruise. William Atkin and I designed the little ship and I had her built at Dr. Graham Bell's laboratory in Nova Scotia, and sailed her across the Atlantic and back again for the fun of the thing and incidentally to cover the International Motorboat Races for *Motor Boat*. Picking one's way across big stretches of water by newly acquired skill with the sextant, pitting one's wits against the big honest forces of nature, feeling the way with lead line through fog and darkness into strange places that the travelers of trodden paths never find at all, are worth the considerable cost, the time and even the risk that are involved in such an undertaking.

Sometimes I have difficulty in explaining this sort of thing as a "pleasure cruise," but I venture to say that if the truth were known we would find that a great many of the big expeditions, things that would make the cruise of the Typhoon sink into insignificance, were undertaken more from a love of adventure than from any profound scientific conviction. I met Bob Bartlett the other night, and you cannot tell me that Captain Bob was inspired by any scientific motive when he went to the Arctic. You cannot tell me that Theodore Roosevelt was driven through Africa and South America by a scientific itch. Of course, these people had a scientific excuse on which to hitch their undertakings, while we had not even a scientific shoestring to cling to. But why have any excuse?

One newspaper came out with a sort of double-barreled editorial in which it praised the cruise of the Typhoon as a "remarkable feat of yachting," but said that it was not sensible yachting nor hardly the thing for American yachtsmen to emulate because of the danger involved. Now we do not advise people to go puttering about the Gulf Stream in small boats in the middle of November, or to cross the Atlantic on the fiftieth parallel at any time of the year, but we hope that if anything comes of all this publicity, it will be to inspire, at least in the youngsters of the country, a desire to get back to the sea. Potentially, we are a seafaring nation. We have the finest coastline in the world and we have a heritage from the clipper ships that made the American ensign known and respected on all the Seven Seas. What we are suffering from in this country is too much common-sense. If you apply a common-sense or a "safety-first" limitation to any sporting venture, you emasculate it into a poor, weak, pale thing, unworthy of the name of "sport." There is no fun in such an undertaking unless it involves an element of danger and hardship.

The Outbound Voyage

The Typhoon is a 45-ft. auxiliary ketch-rigged yacht, 36 ft. on the waterline by 12-ft. beam and 6½-ft. draft. Her lines were drawn by William Atkin and she was built under the supervision of F. W. Baldwin at the laboratory of Dr. Alexander Graham Bell at Baddeck, Cape Breton Island, Nova Scotia. She was powered with a 7½-hp. engine of the high-compression, oil-burning type. Her performance has proved what has been proved time and again by such men as Day and Slocum and Blackburn, that a small boat properly designed and built is as seaworthy as a large one. Structurally, a small boat is stronger than a big one. There are dangers and hardships, of course, in such a cruise, but so far as the boat itself is concerned there need be no question of its seaworthiness.

We had planned to sail on July 1 to reach England by Aug. 10, the day set for the first of the International Motorboat Races, but I found when I reached Baddeck about the middle of June that the boat was nowhere near finished. We launched her finally on July 3, and by eliminating such things as trial trips, compass adjustments and the like, we were ready to hop off by the 18th. Our endless equipment and provisions were thrown aboard.

Then there was the matter of the crew. Baldwin was certain, but we needed two or at least one more man, and at the last minute we picked up James Dorsett, a youngster, who had been working on the Liberty engines of the HD-4; he had never been to sea but was willing to take a chance. We got under way at midnight and chugged out the Bras d'Or Passage under power. Then something went wrong with the engine. In the rush of leaving the city I had failed to visit the factory to learn certain things about the engine and the factory through some oversight had failed to send us sufficient information about various adjustments; in consequence the engine was not used again until we reached England. To make matters worse, we encountered a calm off the Cape Breton coast and our chances of reaching Cowes seemed practically nil. The logical thing would have been to put in to St. Pierre, Miquelon, or some other port and get the engine going, but I was afraid that once in the logical thing would be to stay, for our chances seemed to be about 1 in 100. There was no particular point in crossing if we could not make Cowes in time for the races. Then we encountered a gale and tacitly agreed to keep on for England. Providence favored us with hard southwest winds over the quarter, and under sail alone, and mighty little of that at times, we made the run from Cape Race, Newfoundland, to the Scilly Islands in 15 days 9 hr., driving the craft every minute of the time. Although we got so tired that we could stand but

[1] Managing editor, *Motor Boat*, New York City.

an hour's watch at the wheel without falling asleep, and in spite of the fact that Dorsett was sick most of the way over, although able to take his regular trick, we soon became adjusted to the motion and were able to prepare regular meals and to sleep under any conditions.

Sailing up the English Channel with spinnaker set, we passed through the Needles into the Solent and dropped the hook off the Royal Yacht Squadron at Cowes at three o'clock in the morning the day before the first of the races. We were in time with 36 hr. to spare.

After a week in England Baldwin left us to confer with the Admiralty in regard to his glider, the HD-4, and it was necessary for us to look about for someone to fill his place. Finally a young chap named Fox, who is the master of the Sea Scouts of Cowes, and Hookey, one of his youngsters, signed for the return cruise. Fox had had a bit of cruising experience and Hookey knew enough of open-boat handling to pick up the work readily, and with a full crew of three, we left Cowes for the French coast.

Landfalls on the French and Spanish Coasts

As it was then the last of September there was little time for sight-seeing, and we decided to hit only the high spots and make New York before the winter weather. Crossing the Channel, we put in at a quaint little town called Roscoff on the Brittany coast. Having nothing but small-scale charts of the section, we cannot claim any particular credit for discovering one

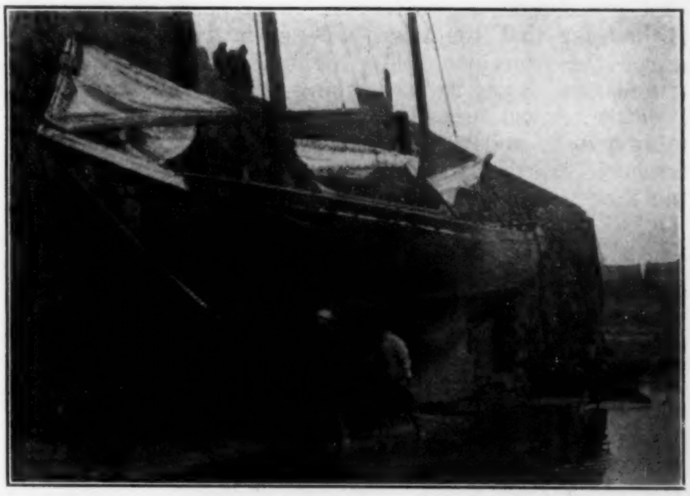
The Typhoon Anchored at Cowes, England

The Author at the Wheel of the Typhoon

of the most picturesque places on the northern coast of France. We blundered in over what looked at low tide to be a range of mountains and spent a most delightful three days. It was our only stop in France. Rounding Ushant, we headed directly across the Bay of Biscay for the point of the Spanish peninsula and in due time picked up the coast in a fog. Appearing first as rocky islands in the sky, the land gradually took form as we approached, great rocky promontories with picturesque beaches between and mountains in the background that were as typically Spanish as if painted by Sorolla. It proved later that we had made the coast within a few miles of Cape Ortegal, our objective, proving that our navigation had been practically perfect, a thing that never failed to surprise me.

The town of Ferrol, indicated on our sailing chart, lay on a sort of indentation between Cape Ortegal and Cape Finisterre, and as this seemed to be a logical place to take on provisions for the hop to the Azores, we continued down the coast and finally reached a remarkable fiord at the head of which the town is situated. Ferrol proved to be the Portsmouth of Spain. Here Vickers of London builds His Majesty's battleships in the same dockyard in which Philip II built the ill-fated Spanish Armada in the sixteenth century. We were not particularly impressed with the place, which like many another military post is provincial and complacently benighted. Except for its harbor, which ranks among the finest of all Europe, and its picturesque qualities which are well up to the backdrops of the Metropolitan Opera, Ferrol left much to be desired. But not so Coruña, which was our next port of call. Coruña is a progressive town, much more typical of Spain, and it successfully counteracted the bad impression left by Ferrol.

From Coruña we took our departure for the Azores which we would have reached in eight days had it not been for a spell of calm weather. After 13 days we



Cleaning the Bottom in an Improvised Drydock at Roscoff, France

sighted the island of San Miguel and got in so close that we could count the toy houses on the cliffs, when a northwest gale struck us, snapping our mizen at the deck and forcing us to lie to under the trisail. For two days we rode it out on the port tack and then came about and rode for another day on the starboard tack, when the wind abated and we were able to hoist sail again and finally made the little island of Santa Maria, 54 miles south of San Miguel. As darkness came on, we made for what appeared to be a deserted little town, as there was not a light to be seen, due to the fact, we learned later, that the windows were all closed up with heavy wooden shutters. Feeling our way carefully with the lead we reached what seemed to be the center of a cove in the cliffs, the tops of which were silhouetted against the sky, and dropped the anchor and turned in. In the morning we found ourselves in the middle of a wonderful amphitheater with tiny pink and blue and buff houses along the shore, back of which miniature rockbound fields extended ladder-like, to the very sky. These fields were filled with grape-vines, each little house had its own wine press and one progressive native owned a still. We were practically out of food, and as we stepped ashore, a bit groggy from hunger, we were welcomed in English, for it proved that most of the natives had served their time in the shoe factories of Massachusetts. They passed us from house to house, wining and dining us, and we found it literally very hard to leave the place that afternoon.

Sailing all night, we made Ponta Delgada the next night and felt our way into the inner harbor with the lead. We found that eight American Shipping Board vessels had been driven into this port for repairs by the gale that had broken our mizzen. Going alongside one of them, the Independent Bridge, whose officers were most hospitable to us, we jerked out our mizzen and made the necessary repairs. The problem of food was a difficult one to solve as there was an embargo on many items, on account of the food shortage in the islands. If you have ever smuggled a dozen eggs in an ordinary business suit, you will appreciate the situation; the percentage of breakage may be small, but the damage is terrific. Even the salt beef and flour that we finally obtained from one of the American vessels had to be smuggled at night, for the little toy soldiers were always on the watch.

After a week at Ponta Delgada, we hopped off for New York. Our leaving was a most inspiring one. Each of the dozen ships then in the harbor broke out its siren and searchlight as we left the inner basin at nightfall; I imagine that the town had not heard such a racket since the American collier Orion beat off the German submarine. Since we were going against the drift of the weather, it was necessary to bend down south for favorable winds, and we headed about southwest until we reached the thirtieth parallel where we encountered a northeaster that lasted for a week during which we logged off 1031 nautical miles. It must have been the tip of the Northeast Trades. Occasionally we used the engine during calms, and all went well until we were pretty well through the Gulf Stream. Even as late as Nov. 10 we swam over the side or hung to the rigging for our morning baths and, except for the fact that our food supply was again nearly exhausted, this part of the cruise was most enjoyable. Instead of putting in at Bermuda, we decided to make for New York and chance it. We laid a course about for Hatteras, assuming that the Gulf Stream would tend to set us north.

All went well until we got about midway between Bermuda and New York on Nov. 15, when a howling northeaster hit us. That afternoon I noticed the masts of a ship ahead of us lifting over the horizon and thought something was coming our way. As we bore down on her she proved to be a three-masted schooner under two jibs and a fully reefed mainsail, pitching a third of her bottom out with each sea and practically hove to. We passed her within 50 yd. to windward, took two photographs and proceeded for New York under full jib and mizzen, much elated over the performance of Typhoon. She was proving herself a regular sea boat.

The Typhoon Receives Two Knockdowns

The second day of the northeaster the Typhoon got her first real knockdown with both mastheads in the water. We were all below except the English youngster, who was at the wheel. The impression I had was that we had been run down. I was in the lee bunk and Dorsett was in the weather bunk on the starboard side. There was a tremendous crash, the cabin was filled with steam from the solid water that came down the Liverpool head; everything on the starboard side, including Dorsett, fell in a direct line and landed on me. I thought that the side of the cabin had come in. Then slowly Typhoon righted herself, due to the 3000 lb. of lead Baldwin had fortunately insisted on placing on the keel in the form of a shoe.

During the night the wind got around to the southwest and increased in intensity, whipping the sea into a mass of confused unstable crests. We had been running under the storm trisail since the night of the first day and as the wind shifted we altered our course so as to run before it. To make steering easier and to prevent broaching-to, we had to put out a long line over the stern and, in an endeavor to hang on to our trisail as long as possible, we put out another line on the end of which was a large iron bucket. But even with this drag astern there was danger of pitch-poling if we ran too squarely before the seas and an equal danger of broaching-to if we took them too broadly over the quarter. I decided that we could not carry the trisail any longer and ordered the crew to bring out the sea anchor which unfortunately was one of those things which had been left unfinished at the start. Most of us have theories about sea anchors and I had taken the precaution to lead the line through a bullnose on the end of the bowsprit so as to get 7-ft. additional leverage to hold her head to the wind. The line was already rove and all that was necessary was to rig the shears in the mouth of the bag, which is 6 ft. square, lash on a pig of lead to keep it submerged and improvise a bridle, and then lower the trisail, luff into the wind and throw the bag over.

I sent Fox forward with instructions to get a life line about him and Dorsett jumped out of the cockpit to assist him in lowering the trisail, when a big sea swept over us, taking my sou'wester and burying Fox to his armpits. Dorsett clung to the mizzen rigging and then started again to claw his way forward along the handrail on the cabin trunk. Then the big crash came. It is not the long swinging regular seas that bother you, the kind we had had for the two preceding days, but the tremendous unstable ones, caused by a sudden change of wind; it was one of these that crashed down upon us, burying us under tons of solid water. I was crouching in the corner of the cockpit with both hands on the wheel and was conscious only of being under solid water. How far over we went I could not tell, but I had a depressed sort of feeling that Typhoon's cruise was over

at last. Then we came up slowly and as the water rolled off of me I looked out to leeward and there, bobbing in an acre of froth, was Jim Dorsett 50 to 60 ft. away from the ship, the air in his yellow oilskins puffing about his shoulders and supporting him. There seemed to be not a ghost of a chance to save him. Fox also had been washed overboard but had got back by way of the mast that had come down on top of him and with admirable presence of mind had lowered the trisail to kill our headway.

I thought of the lines trailing astern and yelled and pointed to them. Dorsett too remembered them, and as we drifted past him under bare poles he struck out and finally got one of them. But our headway was still so great that he was unable to hold on and started sliding down the line; each time he came to the surface he was farther from the ship. Finally he turned on his back and succeeded in hanging on, sort of planing along with his head out of water, and the three of us were able to haul him in under the quarter. As we got him close in he smiled up at us, although half drowned, and said: "Well, fellows, here I am." It was a display of nerve that would have brought tears had we had time for any such emotion. Grabbing him by the oilskins we were unable to lift him aboard, weakened as we were from exertion and from several days' diet of fried flour-paste. As the stern lifted we held him high out of water, only to souse him again when it came down. Finally we pried a leg over the rail with a boathook and I grabbed it and lay down in the waterway, determined that at least we would have a leg. Finally we got him aboard, passed him below and threw over the sea anchor. But as soon as the strain came on the line, it parted and left us in the trough of the sea under bare poles. But we had been in this position for a good 10 min. and nothing had happened, except for the occasional crash of a sea on deck, and so we decided to let her fight it out alone. We went below, opened a bottle of cognac, sang for a while and turned in.

Until I went below, I did not realize just what had happened to us. The floor-boards were up, the heavy slag ballast and in fact everything in the ship seemed to be in a soggy, oily mass on the lee side. The ashes from the stove hit the charts, which were slung up in the intersection of the cabin roof and the side, showing that we had not only been knocked down, but that our masts had been pointing at an angle of practically 120 deg. from the vertical. This all sounds like a very harrowing experience and I am telling it only to prove that a properly designed and built boat will live through anything. The boat is not the determining factor so much as the endurance of the crew.

At Sea

We experienced no difficulty throughout the night except the occasional crash of a big sea on deck, and the next day the wind had gone down to a wholesale breeze. We semaphored a couple of steamers to report us and one chap, not being able to read our signal, hove-to to find out what the strange apparition might be. He was a Spaniard, and since he was decent enough to heave to, I decided to ask him for some food. We came alongside and I passed up my card on the boathook, explaining our predicament. He sent down his card by the boathook, and then we waited and nothing seemed to happen. Finally a sort of caravan emerged from one of his hatches, bearing bags and boxes of food which the crew started to lower away. I held up my hands and explained that we were merely going into New York and not on our way to Europe, but the good-natured skipper kept on lowering food, laughing and pelting us with canned peaches. When he finished there was enough food aboard the Typhoon to take her back the way she had come. It was just one of those courtesies of the sea that are the rule rather than the exception.

As soon as we could decently do so, after dipping our ensign and waving him a farewell, we went below and ate for the rest of the afternoon. It was the most eventful day of the cruise. Our arrival in New York has already been more than adequately covered by the press and it is needless to speak further of it at this time.

EXPORTS OF MINERAL OIL

THE preliminary report of the Bureau of Foreign and Domestic Commerce for 1920 shows exports from the United States of mineral oil totaling 3,100,509,600 gal., compared with 2,492,754,027 gal. in 1919, an increase of 24.4 per cent. In value these represented $549,348,840 against $343,673,432. A comparison of the value of mineral oil exports with those of other commodities such as cotton, breadstuffs, meat and dairy products and cottonseed oil is given in the table in the next column.

VALUE OF MINERAL OIL EXPORTS

	1920	1919
Cotton	$1,136,408,916	$1 137,371,252
Breadstuffs	1,079,085,838	920 301,977
Mineral oils	549,348,840	343,673,432
Meat and dairy products	544,074 050	1,160,643,133
Cottonseed oil	34,874,790	40,890,268
Total	$3,343,792,434	$3,602,880,062

The exports of crude oil and refined products for the years 1917 to 1920, inclusive, are given in the table below.

EXPORTS OF CRUDE OIL AND REFINED PRODUCTS FROM 1917 TO 1920

	1920	1919	1918	1917
Crude oil, gal.	337,886,081	248,821,453	205,829,030	172,121,195
Illuminating oil, gal.	861,891,942	979,155,147	491,109,815	658,156,487
Lubricating oil, gal.	410,874,209	?74,795,166	257,317,253	280 437,663
Gasoline, naphtha, etc., gal.	642,897,428	372,132,957	559,368,855	415,878,844
Fuel and gas oil, gal.	846,959,940	584,849,605	1,200,750,319	1,123,473,047
Residuum, gal.	[1]	32,999,699	244,474	1,051,113
	3,100,509,600	2,492,754,027	2,714,619,746	2,651,118,349

[1]Included with fuel and gas oil.

ELECTROMAGNETIC THEORY

ELECTROMAGNETIC researches are now so comprehensive in their scope that they may be regarded as including, from a broad standpoint, nearly all of the scientific researches comprised within the original meaning of natural philosophy. Chemistry, mechanics, light, heat, and now even gravitation, are claimed as branches of electromagnetics. Perhaps the most recently active field of electromagnetic investigation has been physical chemistry, on the border line of the atomic theory. The interest in atoms has been directed to their constituent electrons. It is curious that the electron, which has been so prominently occupying scientific attention everywhere, is an entity having a mass of less than 10^{27} gram. The number of electrons in a gram of matter is therefore estimated at more than 10^{27}. A convenient method of visualizing a large number of this kind is to consider the size of a cubical box necessary to contain that number of small shot. An ordinary diameter of small bird shot would be 1 mm. On this basis the cubical box that would be necessary to hold 10^{27} shot would be 10^9 mm., or 10^6 meters or 10^3 km., in length of edge. It would be about as long as distance from Norfolk, Va., to Ottawa, Canada. Albeit a gram of matter is supposed to hold that number of electrons, these are not believed to be tightly packed like shot in the hypothetical box. On the contrary, the average distance between adjacent electrons must be very large compared with the dimensions of each electron. The electron is at present the smallest thing known to exist, and is about 50,000 times smaller in "diameter" than the hydrogen atom, which, in its turn, was the smallest thing recognized in science a generation ago.

Since the experimental researches of Millikan have enabled us to study the behavior of individual electrons and to count them one at a time like coins, the belief in the existence and properties of these most minute electrics of the undermicroscopic world has made great advances. Chemical affinities, forces and combinations are assumed to be the stories of the properties and propensities of electrons in their various organized atomic groups.

The recent brilliant investigations of Bragg and Moseley have led to the belief that the 88 known chemical elements, from hydrogen to uranium, occupy a series of simple atomic numbers from 1 to 92 inclusive, with only four missing or unidentified members. To each of these atomic numbers belongs, according to theory, a like number of nucleus electropositive charges and a like number of electronegative electrons.

LANGMUIR'S POSTULATES OCCUPY SCIENTISTS

A very interesting recent theory of Langmuir deals with the constitution and construction of the various 88 chemical elements. Each kind of atom has a three-dimensional structure, approximately spherical in form. The polar axis of an atom is an axis of symmetry, and the equatorial plane perpendicular thereto is a plane of symmetry. By building up spherical aggregations of one, two, three and four units in radius, with "cells" of equal size apportioned among the different electrons, the theory claims to account for a number of the known chemical properties of the different atoms and to satisfy the periodic series originally pointed out by Mendeléeff.

Langmuir's spherical atoms are actually more easily worked with as cubes. The atoms are chemically inert when the number of electrons is such as form simple staple groupings of positive nuclei and negative electrons evenly divided over the surface. Thus, neon with two electrons and helium with $10 = 2 + 8$, two in the inside and eight in the outside shell, are the first two of the highly inert atoms. When, however, the atomic numbers do not fill up the outside shells forces are exerted on the neighboring atoms to bring about a structural union, or chemical combination, that will complete octet groups of electrons between them. In this manner a very fascinating sterochemistry is worked out for a number of atoms and molecules, which is purely electromagnetic in one aspect, purely chemical in another and purely structural in a third.

The Langmuir theory offers so many opportunities for examination and discussion over an enormous field of bald chemical facts, which have hitherto for the most part defied explanation, that it will take the chemists a long time to come to a decision as to the final place of the theory in the general field. It is difficult to decide at first sight how atoms in a given molecular combination behave toward each other on this electron hypothesis. It is advantageous to construct mechanical models of the various component atoms and to study the ways in which these can be brought into mutual contact, with the maximum stability and structural simplicity. The theory is built upon 11 postulates and offers a new view of chemical valences.

EINSTEIN'S THEORY APPEARS WELL FOUNDED

Another subject of investigation which has assumed great scientific prominence during the past year is the Einstein theory of relativity in its latest form. Indeed, the interest in this scientific subject may be said to have overshadowed almost all others during recent months. The theory is admitted to involve three consequences, capable of being experimentally verified and not otherwise explainable; namely, first, a slow rotation of a planetary orbit, which in the case of Mercury takes 149 years to advance through 1 min. of arc, or 3,000,000 years to complete one revolution; second, a bending of light in a powerful gravitational field, as though the light were ponderable material, and, third, a minute displacement of the spectral lines of the sun toward the red end of the spectrum. The first two predictions are declared to have been already verified, while the third is still undecided.

As to the consequences of the theory, they may be regarded as at present unrecognizable to the ordinary observer, inappreciable in engineering or geodesy, appreciable in astronomy, but of very great significance in philosophy or the doctrine of the universe. The remarkable fact, from an electromagnetic standpoint, is that the new space geometry, which is no longer simple Euclidium three-dimensional geometry, is claimed to be in complete conformity with the Maxwellian theory of the electromagnetic field. According to this doctrine, space is not definite, but very large and limited; gravitational force is merely a fictional phenomenon, due to our misinterpretation of the vagaries of geometrical space in the vicinity of matter, and time is indissolubly linked with space. While it is not difficult to obtain an abstract comprehension of this doctrine, on the basis of mathematical equations, it is extremely difficult to obtain a concrete comprehension that can be visualized or constructed. It is pointed out, however, by the protagonists of this remarkable theory that we have no right to deny its validity merely because we have difficulty in visualizing it to our untrained senses.—A. E. Kennelly in *Electrical World*.

Instantaneous Current and Voltage Values In a Battery[1]

By G. W. Vinal[2] and C. L. Snyder[3]

Illustrated With Photographs and Charts

FOR some months the Bureau of Standards has been working upon specifications[4] for starting and lighting batteries at the request of the Motor Transport Corps. These specifications have now been completed and will be published as the appendix to a circular to be issued by the Bureau. Various laboratory tests also have been made on batteries of this class. In addition to these tests it seemed desirable to study the performance of the batteries when in actual use on automobiles. Measurements of the current and voltage of the batteries as made by the ordinary indicating instruments do not give accurate or adequate information because of the rapidly fluctuating values of these quantities. We have therefore measured the instantaneous values of current and voltage from oscillograph records. The variations of voltage and current when the engine is operated by the starter, and the variation of charging current through the battery under running conditions, are shown in the oscillograms that follow.

In the course of the experiments additional information was obtained with respect to the operation of the starter system and the engine itself. It is intended to point out in this paper some of the effects relating to temperature, compression, lubrication, distributor action and flywheel velocity, in addition to the battery characteristics. The results which are given are suggestive only of the possible application of this method for the study of the performance of starter systems and internal-combustion engines. It is believed that a development of this method will provide an easy and exact method for studying the operation of the various parts. This method was found entirely satisfactory for studying the problems connected with the battery.

Experiments have been made on a number of different cars but the most systematic and comprehensive series of measurements were made on a Dodge car which has been driven about 15,000 miles and a Cadillac car, which has been driven 18,000 miles. Most of the curves used as illustrations in this paper were obtained from these cars. All of the cars tested were in ordinary running order.

Methods and Apparatus.

The instantaneous values of current and voltage were obtained by a three-element moving-coil type oscillograph. To obtain records for periods of long duration, the ordinary film drum was replaced by a camera of special construction in which bromide paper in rolls 100 ft. long was used. When making a record, the sensitized paper was wound upon a drum in the lower end of the camera after having passed the oscillograph slot through which the recording images were projected. One of the elements was used to record the voltage at the terminals of the battery,

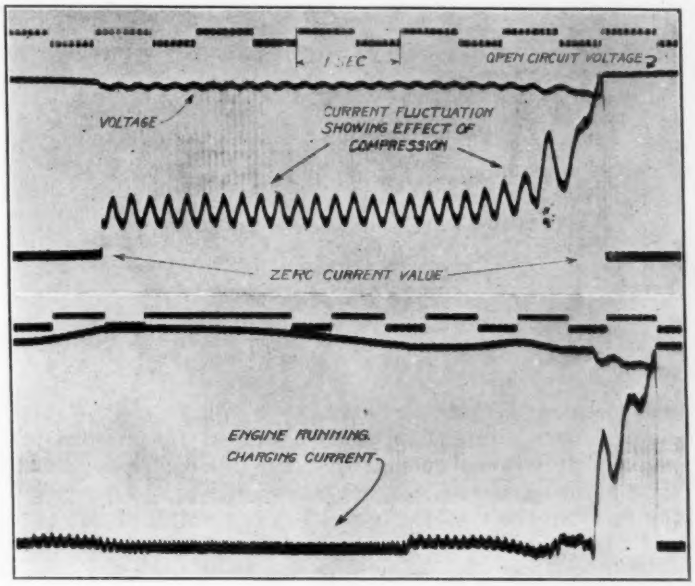


Fig. 1—Record of Current and Voltage in the Battery Circuit of a Dodge Car (Above) when the Starter Was Cranking the Engine without Ignition and (Below) when the Engine Was Running

another the current through the battery circuit, and the third the time record, which consisted of the ½-sec. ticks of a chronometer.

The camera was arranged so that the photographic paper moved at a uniform speed, irrespective of the amount of paper remaining in the camera. It was possible, however, to change the speed of the paper at will. Some of the records have been made with the paper moving at low speeds, about 2 cm. (0.787 in.) per sec., others at an intermediate speed of 3½ cm. (1.378 in.) per sec., but most of them at high speed, 7½ cm. (2.953 in.) per sec.

To measure the current through the battery circuit, a shunt of 0.006 ohm. resistance was inserted in the circuit at the battery. Potential wires from this shunt were connected with the current element in the oscillograph. Measurements of the current and voltage were made simultaneously by an ammeter and a voltmeter. These meters have too slow a period to give the initial values but the readings gave satisfactory average values for the current and voltage when the starter was operated at a uniform rate. Such readings were used as a check upon the calibration of the elements in the oscillograph. The deflections of the elements are approximately proportional to the current or voltage measured. In some cases, however, a deviation was found, which may have been due to the slight tension of the element. The tension was necessarily reduced to a minimum to give sufficient deflection. It was found necessary to calibrate the current and voltage elements with steady currents and voltages which could be accurately measured. This calibration

[1] Published by permission of the Director of the Bureau of Standards, Washington.
[2] Physicist, Bureau of Standards, Washington.
[3] Assistant physicist, Bureau of Standards, Washington.
[4] See The Journal, December, 1920, p. 559.

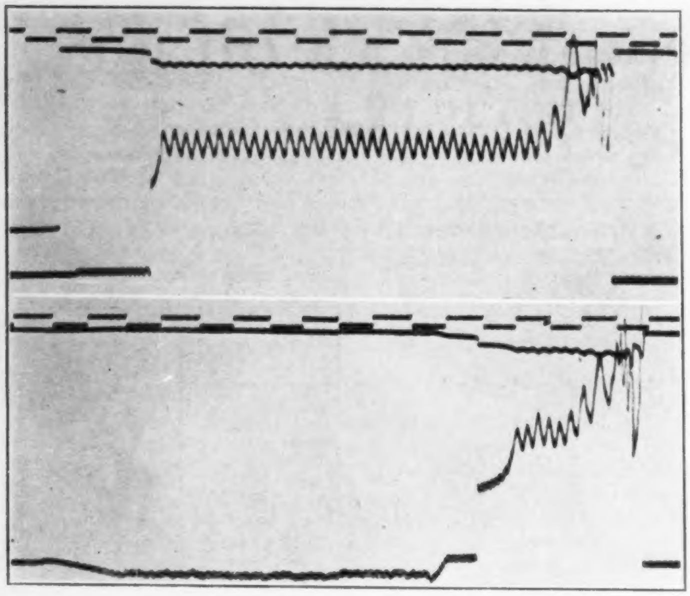


FIG. 2—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A FORD CAR OPERATED (ABOVE) WITHOUT THE IGNITION AND (BELOW) WITH THE ENGINE RUNNING

was necessarily repeated each time the tension of any element was altered, or when the gold fuses were replaced. It will be noticed that the ½-sec. ticks of the time record are unequal. This was due to the action of the relay in the circuit. From the beginning of one second to the beginning of the next can, however, be considered as 1 sec. to a very high degree of accuracy.

VARIATIONS IN VOLTAGE AND CURRENT.

The general character of the curves obtained is shown in the following figures. All of these oscillograms begin at the right and are therefore to be read from right to left. A more detailed examination of these and similar figures will be given in the later sections. The upper portion of Fig. 1 shows curves for the Dodge car, equipped with Northeast starter system, Model D, and Willard battery, type SJR-26. The time intervals are recorded at the top of the record. The two curves below represent the fluctuations of the voltage and current of the battery when the starter is in operation. The successive peaks of the latter show the increase of current for each compressive stroke. The lower half of this illustration shows the operation of the same system with the ignition. It will be seen from the curve that the engine started on the second compression, somewhat less than 1 sec. after the starter-switch was closed. The variations in the current curve will be explained later. Fig. 2 shows similar observations made on a 1920 Ford car that had run 5000 miles. The initial current values of both portions of this illustration are beyond the limits of the paper. During the first half second the current fluctuated violently between 200 and 300 amp. In the upper portion of Fig. 2 it will be seen that the minimum voltage values correspond with the maximum current values. This is true of the other illustrations also, but in most of them it is not as clearly seen as here. The engine was started with the ignition on the battery in the lower portion of this illustration. The discontinuous point in the current curve shows the time at which the starter-pedal was released. A corresponding rise in the voltage is to be observed. Fig 3 was obtained on a Chalmers car (35A, 1917 model) which had been driven 12,000 miles. The characteristics shown are somewhat similar to those in Fig. 2. Fig. 4 was obtained on a four-cylinder Studebaker car that had been driven 20,000 miles. These curves are without the violent fluctuations observed during the first half second in the case of the two preceding illustrations. Fig. 5 shows curves for the eight-cylinder Cadillac car. The initial current was approximately 410 amp., decreasing to an average running value of about 150 amp. as shown in the upper section. In the lower portion the ignition

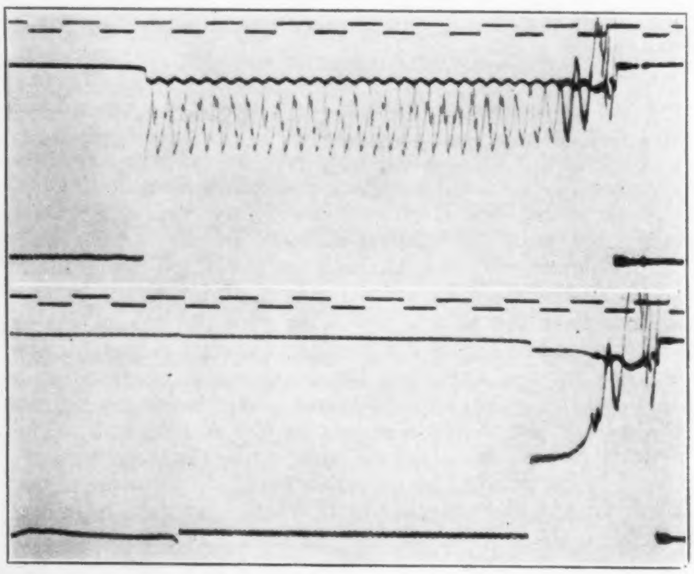


FIG. 3—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A CHALMERS CAR OPERATED (ABOVE) WITHOUT THE IGNITION AND (BELOW) WITH THE IGNITION

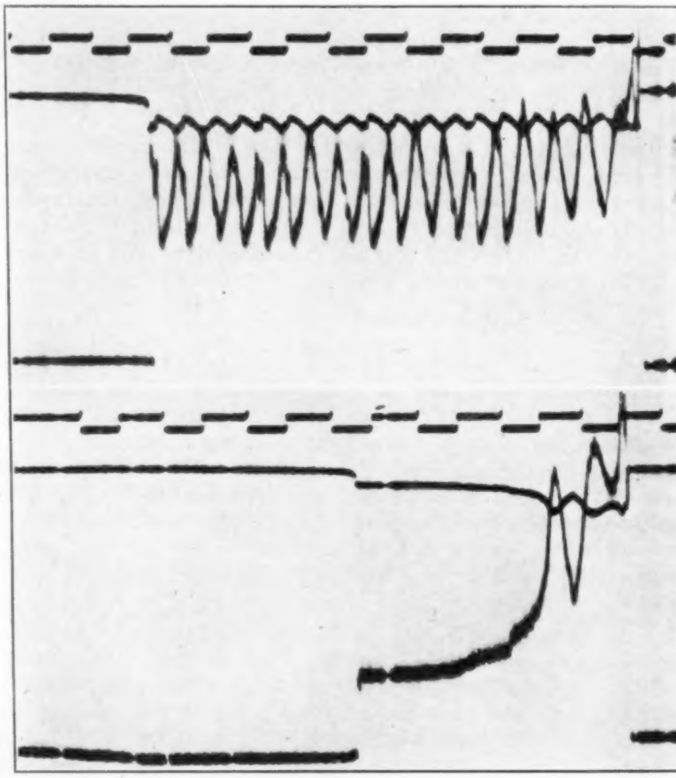


FIG. 4—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A STUDEBAKER CAR OPERATED (ABOVE) WITHOUT THE IGNITION AND (BELOW) WITH THE IGNITION

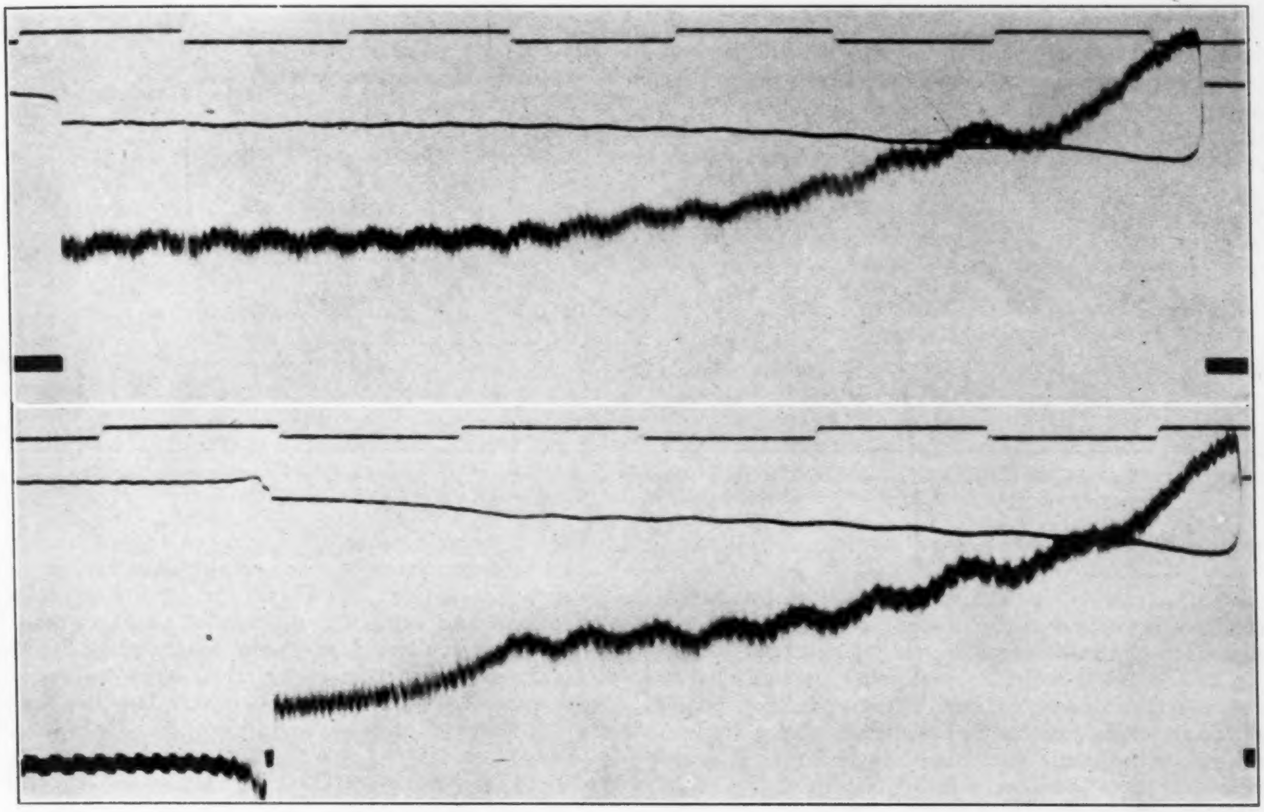


FIG. 5—RECORD OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF A CADILLAC CAR (ABOVE) AS THE STARTER CRANKS THE ENGINE WITHOUT THE IGNITION AND (BELOW) WITH THE IGNITION

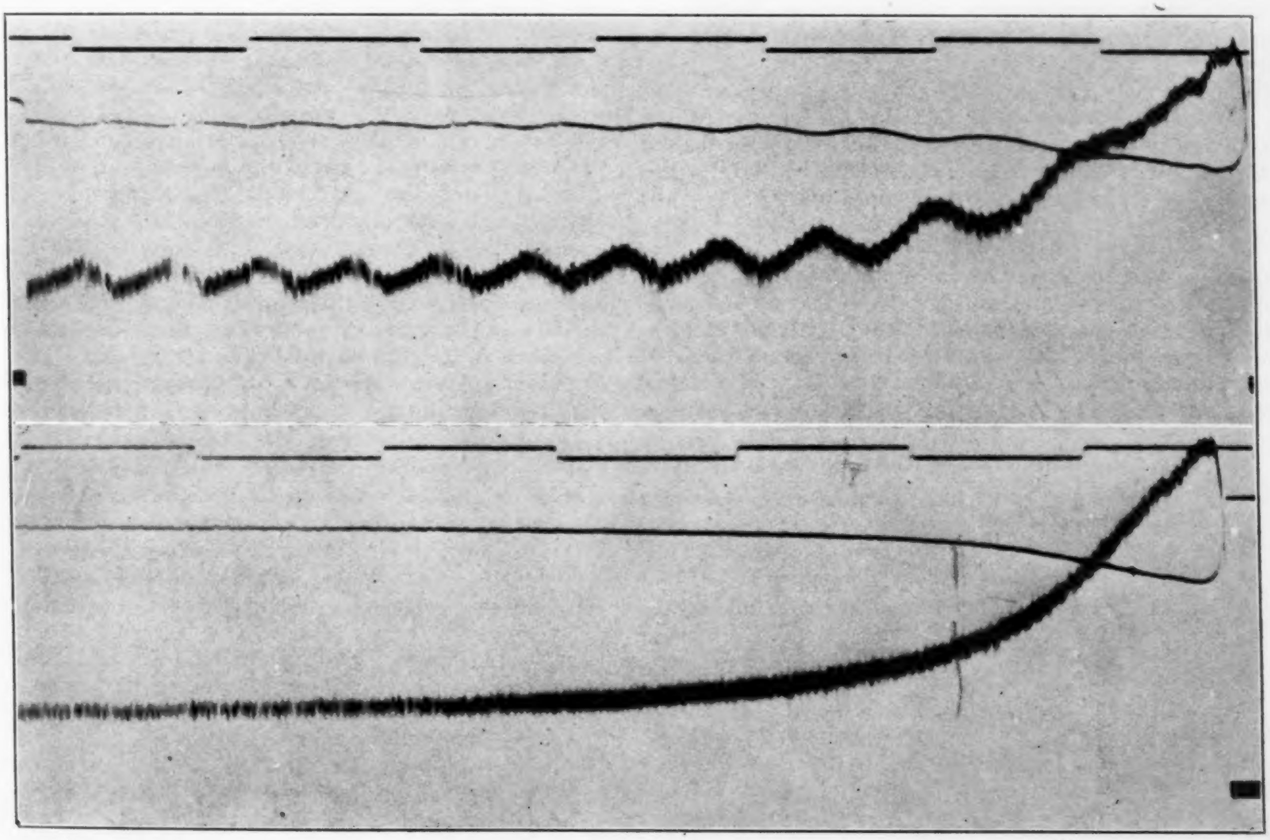


FIG. 6—CURRENT AND VOLTAGE CURVES OBTAINED FROM A CADILLAC CAR (ABOVE) WHEN ALL THE SPARK-PLUGS WERE REMOVED FROM ONE BANK OF THE ENGINE AND (BELOW) WHEN THE SPARK-PLUGS WERE ENTIRELY REMOVED FROM THE ENGINE

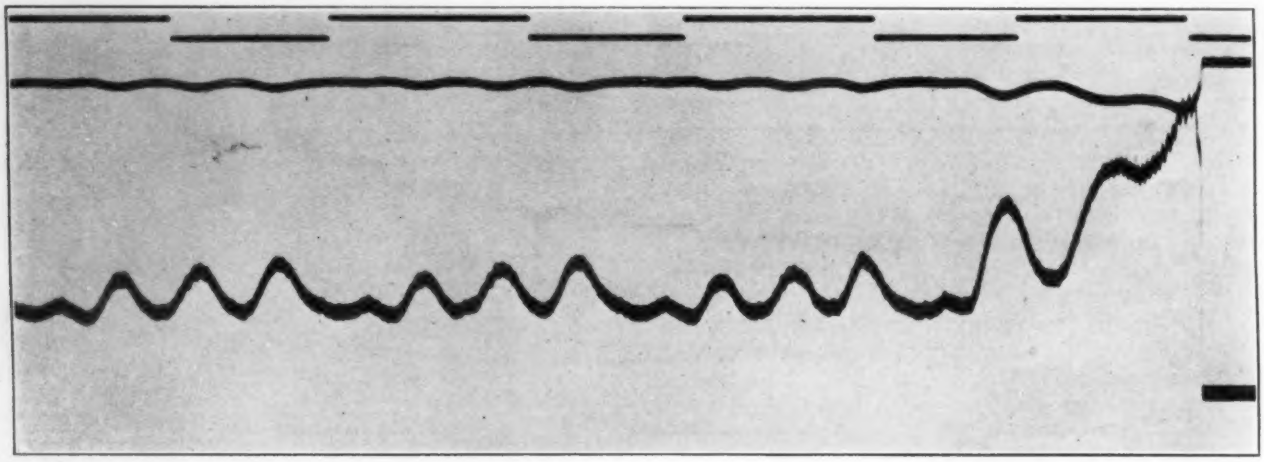


FIG. 7—RECORD OBTAINED AFTER A PET COCK HAD BEEN REMOVED FROM ONE CYLINDER OF A DODGE CAR TO SHOW THE EFFECT OF COMPRESSION ON THE CURRENT AND VOLTAGE OF THE BATTERY

switch was closed and the engine started at the end of $2\frac{1}{4}$ sec.

In the illustrations for the various cars characteristic differences are evident in the current and voltage curves. A comparison of these curves shown in the upper part of Figs. 1, 2, 3, 4 and 5 indicates that some are more nearly sine curves than others. These differences are probably characteristic of differences in the design of the engines. By making an harmonic analysis of such curves it might be possible to trace the effects of the timing of the valves and other factors. For such an analysis it would be desirable to increase the time scale as has been done in Fig. 6, but we have not attempted such an harmonic analysis in this paper. The lower sets of curves in Figs. 1 to 5 inclusive show characteristic differences in the starter systems, particularly between the single and two-unit systems.

The sensibility of the oscillograph was not the same for all of the measurements, and some differences in the appearance of the curves have been caused by variations in the intensity and width of the beam of light. The cars were all in ordinary running condition.

EFFECT OF TEMPERATURE.

Fig. 6 shows the effect of the temperature of the engine on the current and voltage required for starting. The engine was operated by the starter without ignition. These curves were obtained on the Dodge car at radiator temperatures of 20, 50 and 77 deg. cent. (68, 122 and 171 fahr.) respectively. The initial values for current and voltage have been read from these curves and tabulated in Table 1, together with the values obtained when the speed was constant. The average operating values of the current and voltage at a constant speed as read from the curves agree closely with the values given by the indicating instruments in the circuit. The difference between the maximum and minimum values at a constant speed is the amplitude given in the table. It will be seen by comparing the results for the Dodge car at 20 deg. cent. (68 deg. fahr.) with those at higher temperatures that the initial starting current does not decrease in the same proportion as the operating current, when the temperature is increased. This indicates that the initial current which the battery must supply depends more upon the inertia of the system than upon the temperature of the engine. The average operating current at 50 deg. cent. (122 deg. fahr.) is practically the same as the current at 77 deg. cent. (171 deg. fahr.). A change is to be noted, however, in the amplitude of the fluctuations. At 20 deg. cent. (68 deg. fahr.) the amplitude is 36 amp., at 50 deg. cent. (122 deg. fahr.) 28 amp. and at 77 deg. cent. (171 deg. fahr.) 16 amp. The significance of these changes will be brought out more clearly later on. Upon examination of these curves with reference to the time scale, it will be seen that the speed of the engine can be computed easily since there are two compressions for each revolution of the crankshaft. The values for the Cadillac car given in Table 1 have been computed from 11 oscillograms which are not shown as illustrations. The power required initially to start the system in motion and the

TABLE 1—INSTANTANEOUS AND AVERAGE VALUES OF CURRENT AND VOLTAGE FOR AUTOMOBILE BATTERIES

Car	Temperature of Radiator Water		Engine Speed, R.P.M.	Throttle	Initial Values		Average Operating Values		Amplitude of Current, Amp.	Power Required, Watts	
	deg. cent.	deg. fahr.			Current, Amp.	Voltage	Current Amp.	Voltage		Initial	Average Operating
Dodge	20	68	116.8	Closed	136	10.30	62	11.10	36	1,400	688
Dodge	50	122	162.6	Closed	127	11.10	38	11.80	28	1,410	449
Dodge	77	171	150.9	Closed	117	11.10	40	11.80	18	1,300	472
Cadillac	25	77	89.0	Closed[5]	455	4.64	133	5.61	..	2,110	746
Cadillac	25	77	90.0	Open[5]	449	4.62	137	5.62	..	2,073	770
Cadillac	35	95	91.6	Closed	400	4.57	136	5.38	..	1,826	732
Cadillac	35	95	94.6	Open[5]	409	4.44	140	5.36	..	1,814	752
Cadillac	65	149	93.7	Open[5]	417	4.46	138	5.37	..	1,860	742
Cadillac	69	156	100.0	Closed	432	4.56	148	5.40	..	1,984	800
Cadillac	82	180	96.0	Open	417	4.42	154	5.38	..	1,842	829

[5] Results given are the mean of two determinations.

average operating power when the speed was constant show little change due to temperature above 35 deg. cent. (95 deg. fahr.). It will be noticed in the table that slightly more power is required initially to start the system when the throttle is closed, but that the average operating power is less if the speed remains constant. The latter result may be due to effects produced by the greater compression in the cylinders when the throttle is open. As these observations were made in the summer, it was not convenient to obtain temperatures below those given in the table. The power required to overcome the inertia of the system is somewhat less than the lowest figure given in next to the last column of Table 1. The power required to overcome the compression is practically constant irrespective of the temperature, provided the throttle opening is fixed. The power to overcome friction would probably increase rapidly at temperatures below those recorded here, as is indicated by the upper portion of Fig. 6. The increase in average operating power required for the Cadillac at the highest temperatures suggests increased friction. The engine had been run for a considerable period of time to increase the temperature. The oil and bearings had become heated and it is probable that the bearings were tighter at the higher temperatures because the engine had just been overhauled. Similar effects might be produced by insufficient lubrication at these temperatures.

Effect of Compression and Lubrication

To demonstrate clearly that the fluctuations in the current curve are due to compression in the cylinders, a run was made in which one priming-cup was removed.

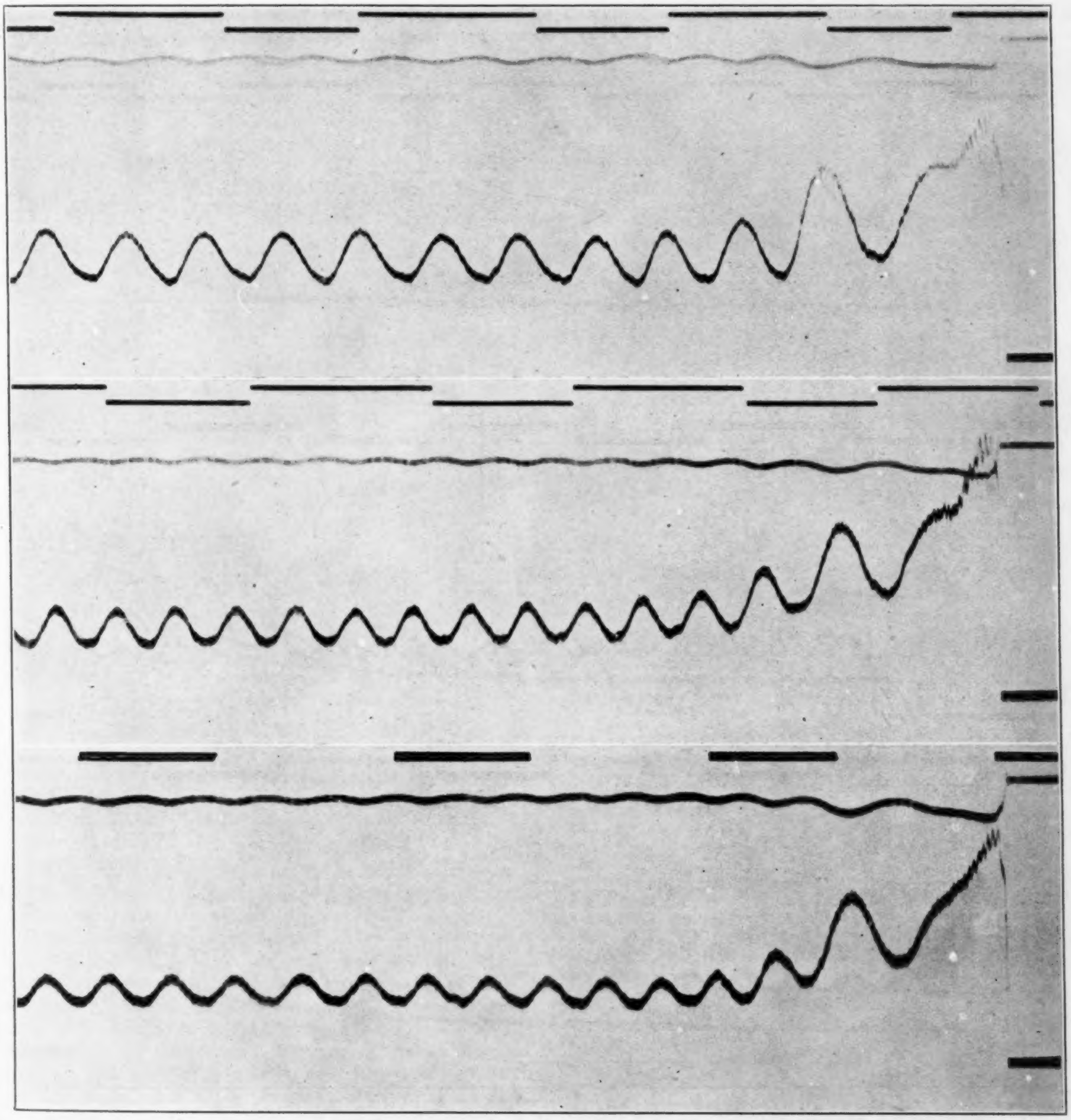


Fig. 8—Record from a Dodge Car Obtained with Radiator Temperatures of 20 Deg. Cent. (68 Deg. Fahr.), 50 Deg. Cent. (122 Deg. Fahr.) and 77 Deg. Cent. (171 Deg. Fahr.)

The results of this experiment on the Dodge car are shown in Fig. 7. This illustration shows that there was only a slight compression in the cylinder that was open.

The power furnished by the battery is expended in several ways. A small part is used up within the starter itself. This can be measured as in the case of any electric motor. A second part is expended in compressing the gas within the cylinders. A third part is expended in overcoming friction in the engine and varies with the speed and the lubrication. A fourth part is used for ignition on some cars. The amount of power which the battery furnishes can be obtained for any instant by multiplying the instantaneous values of current and voltage. If this product is multiplied by an increment of time we obtain the total energy, or work done by the battery during this instant of time.

It is evident, therefore, that careful measurements of the electric power and time can furnish information as to the amount of work being done by the battery during any part of a cycle. One significant result of this can be seen in Fig. 7, where it will be observed that the engine speeds up in passing what would have been the compression stroke of the cylinder had the priming-cup not been removed. As there was no compression in this cylinder, no energy could be returned to the system by compressed gas. The increased time required to reach the next maximum shows that the engine decreased in speed. This fact is determined by measuring the distance between the successive maximum values of the curve. A rolling effect results which can be noticed by the difference in height of the successive maximum values. The watts delivered by the battery can be used as a sensitive and exact method of determining the instantaneous speed of the flywheel. The greater the inertia of the flywheel the smaller will be the fluctuations of the current and voltage curves.

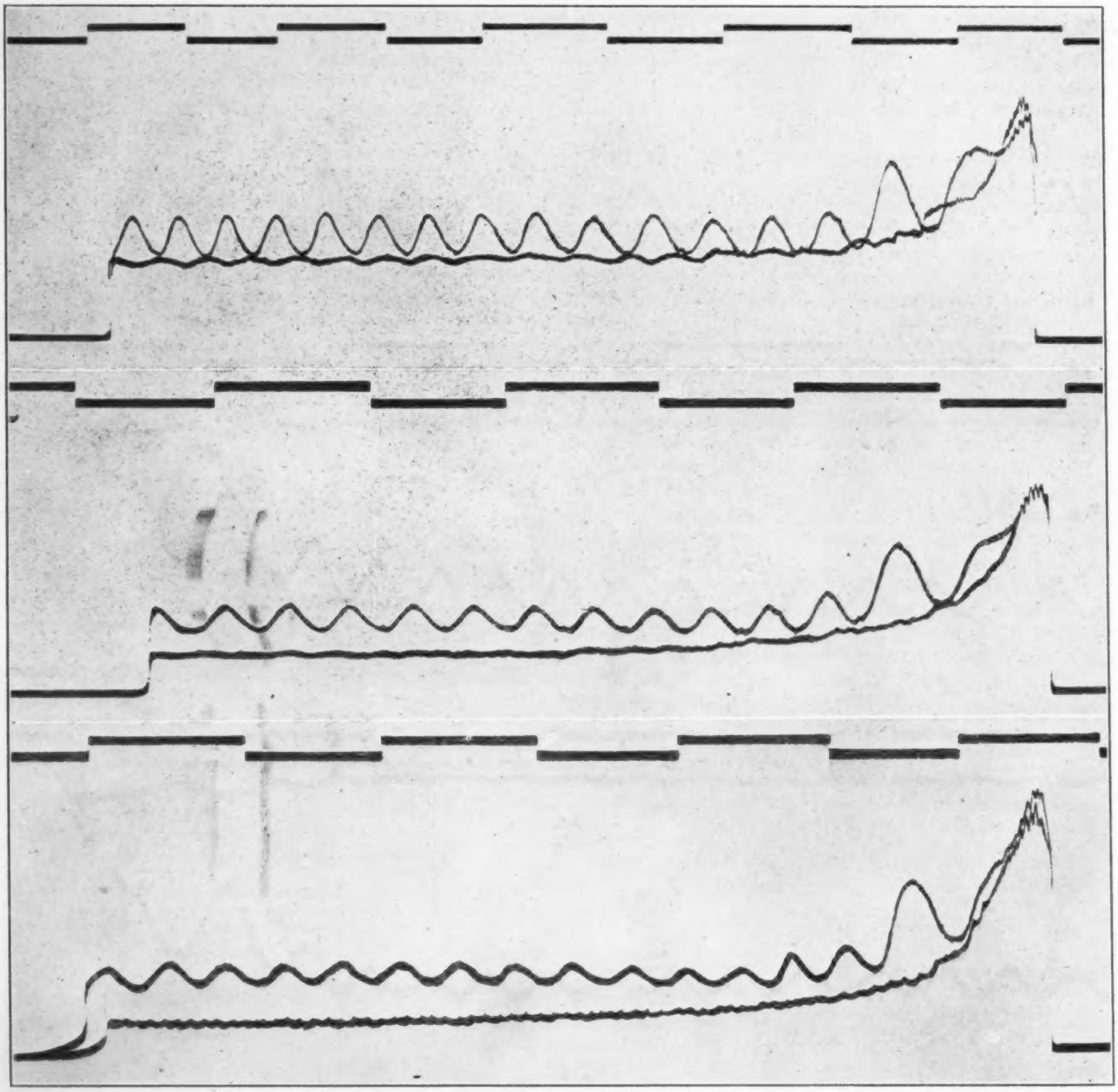


FIG. 9—REMOVING ALL THE SPARK-PLUGS IN A DODGE CAR ELIMINATED TO A GREAT EXTENT THE FLUCTUATIONS IN THE CURRENT CURVE OF THE BATTERY

The Radiator Temperatures at Which These Curves Were Obtained Were 20 Deg. Cent. (68 Deg. Fahr.), 47 Deg. Cent. (117 Deg. Fahr.) and 84 Deg. Cent. (183 Deg. Fahr.)

The curves of Fig. 8 (Dodge car) show a decreased amplitude at the higher temperatures. This suggests the conclusion that the amplitude for this type of engine depends on lubrication as well as compression. The effect due to friction is least at the top and bottom of the stroke and greatest when the crank arm and the connecting rod are at right angles. This result has been confirmed by experiments, using one bank of the Cadillac engine.

It is possible to separate the effect of compression from that of friction and other losses, by relieving the compression in all of the cylinders. This might best be done by removing the head of the engine, but in these experiments the compression was more conveniently relieved by removing the spark-plugs. A series of comparative measurements, the results of which are shown in Fig. 9, were made on the Dodge car at three different radiator temperatures, 20, 47 and 84 deg. cent. (68.0 116.6 and 183.2 deg. fahr.), respectively. These figures

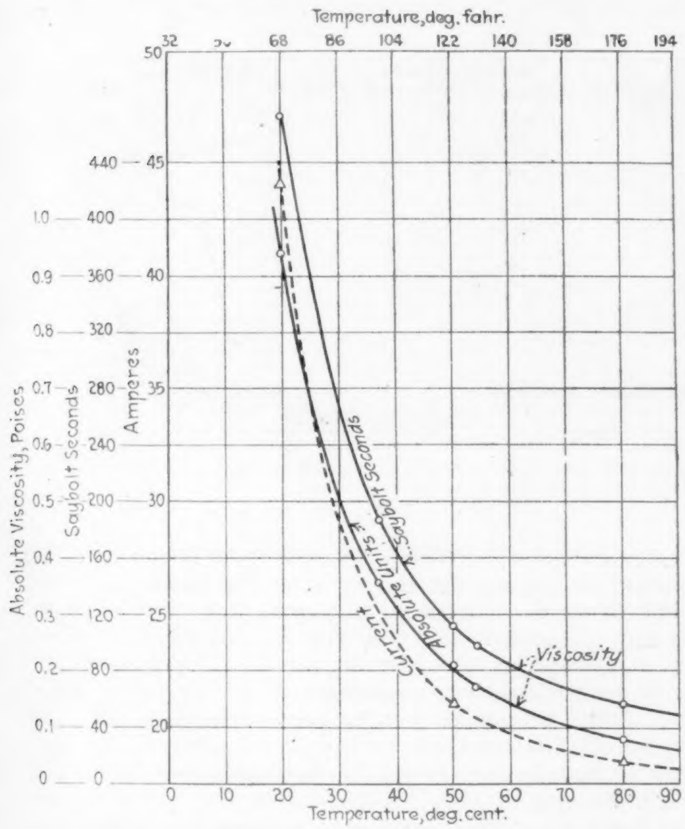


FIG. 10—RELATION OF THE ELECTRIC CURRENT IN THE STARTER CIRCUIT TO THE VISCOSITY OF THE OIL USED IN THE ENGINE
The Current Values Were Those Given by the Curves in Fig. 9 and Are Plotted against the Temperature

show that the curves obtained when the spark-plugs were removed are devoid of the marked fluctuations of current observed when the spark-plugs were in place. At each temperature a record of the current values was made with the spark-plugs in, followed by an exactly similar measurement with the spark-plugs removed. The corresponding curves for each temperature have been superposed and traced together in Fig. 9, care being taken to make them in perfect register, as to the beginning of the curves and their position with respect to the horizontal axis. The results obtained at 20 deg. cent. (68 deg. fahr.) show that the curve without compression is practically tangent to the lower values of

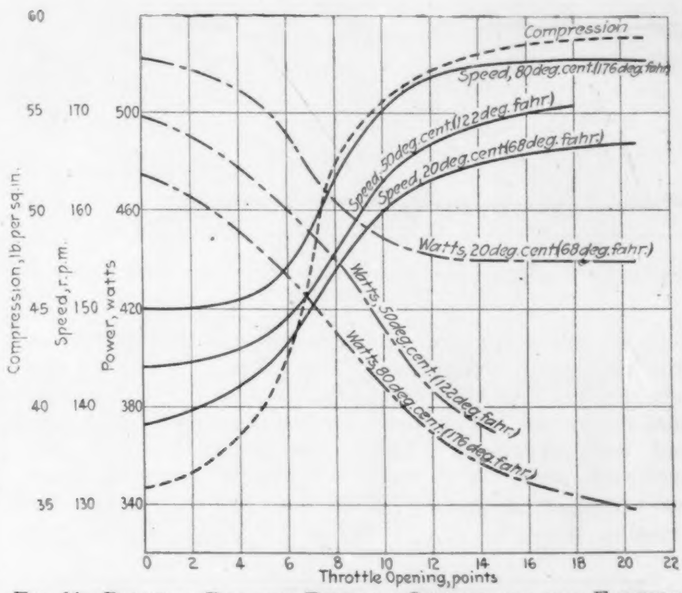


FIG. 11—RELATION BETWEEN THROTTLE OPENING AND THE ELECTRIC POWER IN WATTS DELIVERED BY THE BATTERY OF A DODGE CAR IN CRANKING THE ENGINE AT TEMPERATURES OF 20, 50 AND 80 DEG. CENT. (68, 122 AND 176 DEG. FAHR.)

current when the spark-plugs are in position. At the higher temperatures this curve falls somewhat below the minimum current values. The upper portion of Fig. 6 shows the results of an experiment on the Cadillac car with the spark-plugs removed from the left bank. By comparing this with the upper section of Fig. 5, the overlapping effect of the cylinders can be seen. The lower half of Fig. 6 shows the results of an experiment on the Cadillac car in which all spark-plugs had been removed. The same high value of the initial current is

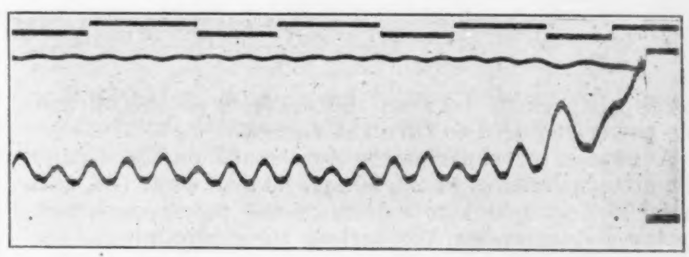


FIG. 12—EFFECT OF A PARTLY OPENED VALVE IN ONE CYLINDER OF A DODGE CAR ON THE CURRENT CURVE WITH THE IGNITION OFF

to be noted here as in the upper portion of Figs. 5 and 6. If the two sections of Fig. 6 were superposed, the current curve of the lower portion would be tangent to the bottom of the current curve of the upper section.

One of the curves given in Fig. 10 shows the relation

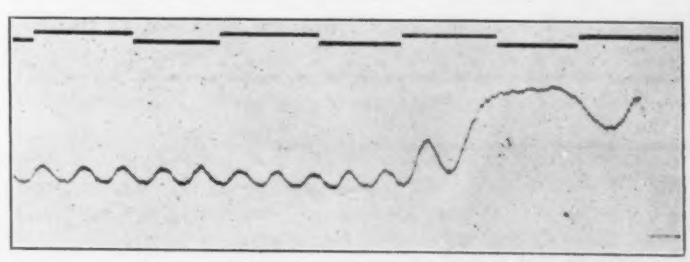


FIG. 13—A STICKING OF THE ENGINE AFTER DRAWING AIR DIRECTLY INTO THE CYLINDERS OF A DODGE CAR IS SHOWN IN THIS CURRENT CURVE
The Record Was Obtained at a Temperature of 47 Deg. Cent (117 Deg. Fahr.) after the Spark-Plugs Had Been Replaced.

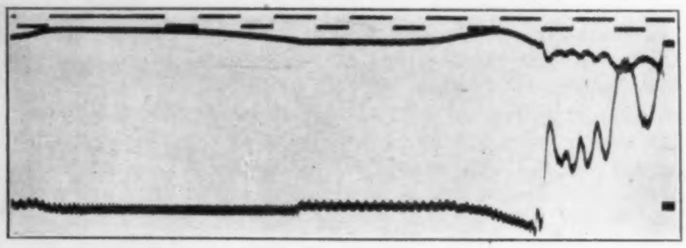


Fig. 14—Sticking of the Engine also Resulted after the Pet Cock Had Been Replaced

between the temperature and viscosity of the oil used in this particular Dodge car. The other curve gives the relation between the temperature and current values used in turning the engine after the inertia of the system had been overcome. These are plotted to a purely arbitrary scale. The marked similarity between these two curves would suggest a decrease in friction with increasing temperature. These curves show that a proportionality exists between the viscosity of the oil and the power required to turn the engine.

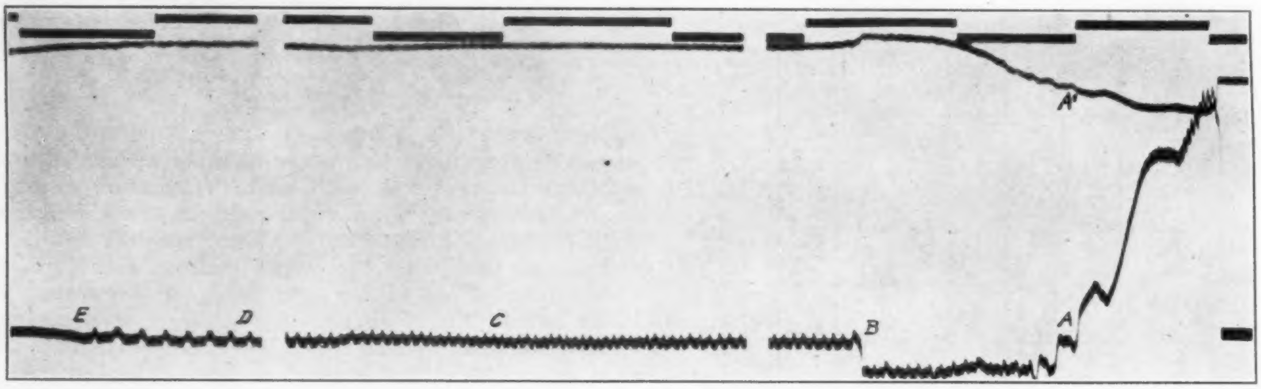


Fig. 15—Curve Showing the Starting of the Dodge Engine on the Second Compression and the Characteristics of the Charging Current

A number of experiments were made on the Dodge car at temperatures of 20, 50 and 80 deg. cent. (68, 122 and 176 deg. fahr.) to determine the power consumed by the starter system for various throttle-openings. In Fig. 11 we have plotted the values read from the oscillograms for power and engine speed plotted against an arbitrary scale of throttle-openings. We have also plotted the compression curve as measured by a gage for the same throttle-openings as well as these could be determined without the use of fixed orifices in the carbureter.

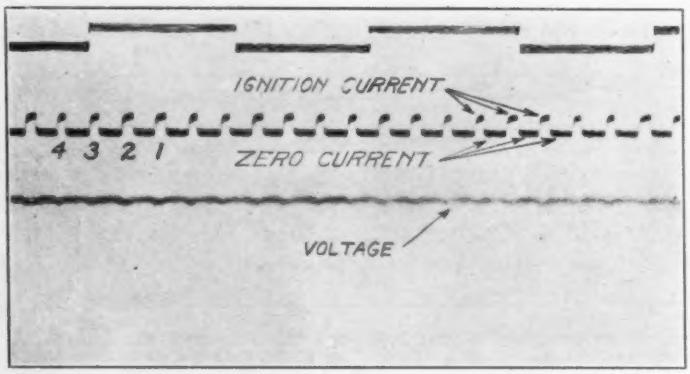


Fig. 16—The Ignition Current when the Engine of a Dodge Car Was Running Slowly

It appears that if the amount of energy lost in the starter itself is known and deducted, and the compressive measurements of the lubricating properties of difsion released by removing the spark-plugs or the head of the engine, the electrical power necessary to overcome friction can be calculated. In this way, comparaferent oils and friction losses in various parts of the machine might be made under running conditions.

At this point it may be interesting to examine a curve which was obtained when one of the four cylinders of the Dodge car was leaking. The exact cause of the leak is not known, but is supposed to have been due to a particle of carbon lodged in an exhaust valve. A curve showing the result is given in Fig. 12, in which it will be noticed that every fourth maximum is considerably lower than the others.

One peculiar phenomenon was observed in the experiment with the spark-plugs out. It was found that in some cases where air was drawn directly into the cylinder, either by removing the spark-plugs or taking out the priming-cups, greater demands were made upon the battery to operate the starter after the spark-plugs had been replaced. That is to say, more work was required to turn the engine over. In Fig. 13, this effect is shown by the shape of the current curve. This record was made with a radiator temperature of 47 deg. cent. (116.6 deg. fahr.) immediately after the spark-plugs had been replaced. The curve shows the initial effort of the battery to have been exceeded by a second maximum which lasted for more than ½ sec., during which the engine did not turn. After gradually passing this maximum the normal operation was restored. The same phenomenon is observable in another curve, Fig. 14, which was made immediately after an experiment in which a priming-cup was removed from one cylinder. Here again it is seen that the first compression stroke, that of the cylinder from which the priming-cup had been removed and replaced, required as much power as was initially expended by the battery in starting the system in motion. The gas which was contained in the cylinder at this time was of course expelled by the succeeding stroke, but an excessive power consumption was again observed on the next compression in this cylinder, as shown by the fourth maximum. The ignition-switch was on during this experiment and the engine began to operate on the next stroke; hence, it is not possible to tell whether this effect persisted. The cause of this peculiar characteristic is not known.

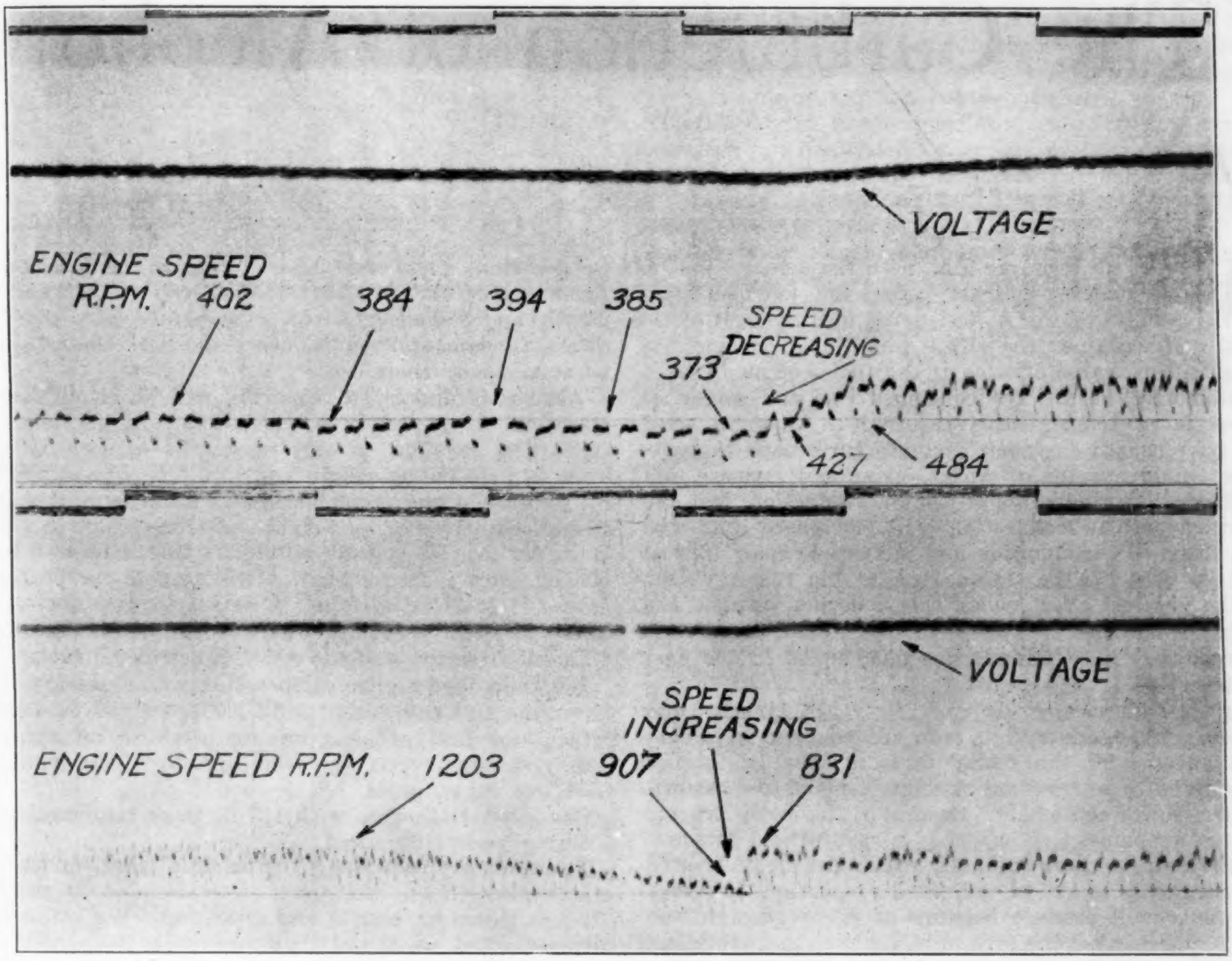


FIG. 17—VARIATION IN THE CHARGING CURRENT DUE TO CHANGING ENGINE SPEED
The Upper Curves Were Obtained at a Lower Speed Than Those Underneath

CHARACTERISTICS WITH THE IGNITION ON

Experiments upon the Dodge car similar to those shown in Fig. 8 have been made with the ignition on. One of the curves which has been thus obtained is shown in Fig. 15. Here the initial value of the current was 136 amp., which is exactly equal to that of the corresponding curve in the top portion of Fig. 8. Also the initial value of the voltage, 10.3, is the same. The engine started on the second compression and the current values fell below the initial line, which indicates that the battery was being charged. An immediate rise in the voltage curve to a point above open-circuit voltage shows this to be true. At the point *A* on the voltage curve is a short horizontal region where it is probable that the reverse-current-relay operated. The charging voltage rises to 2.7 per cell or 16.4 for the battery as a whole. This high-charging voltage was due to the high rate at which the battery was being charged during the time that the starter-switch was still closed. At the point *B*, the starter-switch was released. An immediate decrease in the charging voltage and the charging current is observed. The charging current is seen to have decreased at regular intervals, the spacing of which varies with the speed of the engine. The engine was racing at *C* and slowed down at *D*. The ignition was cut off at *E*. It will be noted that these fluctuations in the charging current ceased at the time the ignition was cut off. Further study to determine the cause of these fluctuations showed that they occur every time the circuit is made through the primary coil of the ignition system. A magnification of these current fluctuations is shown in Fig. 16. Here it will be seen that the duration of time that the current flowed through the primary coil was appreciably longer in the case of the contacts marked 1 and 2 than for those marked 3 and 4. This inequality in the action of the contact points is probably due to inequalities in the cam which operates the contact points or possibly to wear in the distributor camshaft bearings. By comparing Fig. 16 with the lower portion of Fig. 5, it will be seen that the shape of the fluctuations in the current charging curves is materially different in the case of the Dodge and the Cadillac cars, although both have Delco systems for ignition. The difference is explained by the difference in the cams in the distributors.

Since the current passes through the primary of the ignition coil twice for each revolution of the crankshaft of the Dodge car, it is possible to determine the exact speed of the engine by measuring the distance between any given number of these points in the charging curve with respect to the time scale. This is possible for the Cadillac car also, for which there are four contacts for each revolution. The exactness with which the speed of rotation can be measured by this method affords the possibility of determining small changes in the velocity

(*Concluded on page* 364)

The Carburetion of Alcohol

By A. W. Scarratt[1]

Columbus Farm Power Meeting Paper *Illustrated with* Charts

We are all very familiar with the demands of the automotive industry upon the petroleum resources of this country, and also the rest of the world, and we know the effect which this demand has had upon the characteristics of the fuels commonly used in automotive work. The continued rise and spread of the range of temperatures required to vaporize these fuels have caused engineers, manufacturers and the public an untold amount of worry, grief and expense, not only from the standpoints of design, production, cost and operation, but in connection with increased fuel and lubricating oil consumption and increased repair bills of all kinds that can be traced back to the fuel problem. But the greatest effect which this abnormal demand has created is reflected in the price per gallon of gasoline which in the United States has quadrupled in the past 10 years.

The ever-increasing demand for cars, trucks and tractors in this country has been accompanied by a continual advance of the power farming idea in foreign countries, with a resultant foreign demand for American farm-power equipment. Several of the larger tractor building companies are enjoying a healthy and continually increasing export business, which can be cultivated and brought up to almost unlimited proportions provided the builder will produce tractors of proper design and construction to meet the farming conditions and operating requirements as they prevail, and at a price which makes it possible for the foreign customer to buy. In general, the size and construction of the first-class American tractors are satisfactory. The greatest obstacle confronting most of them is the use of foreign fuels in an economical and satisfactory manner. Cuba, Brazil, Argentina, Chile, Porto Rico and Venezuela are fertile fields for the American tractor and lie at our door, so to speak, but in these countries petroleum fuels are very expensive; while, on the other hand, alcohol, which is produced in vast quantities, is very cheap by comparison. Naturally, if American tractors are to succeed in these countries they must be equipped to operate on alcohol in an economical and efficient manner. Many manufacturers claim that their engines will operate on alcohol, and they will, but in a very inefficient and wasteful manner because they are not primarily designed with a view to using alcohol as a fuel.

Developing an Alcohol Tractor Engine

We have notions as to what should be done to an engine in order that it will operate on alcohol but few of us have had to put our ideas to work and prove them in the dynamometer room and in the field. The Minneapolis Steel & Machinery Co. has exported a large number of tractors in the past 12 years, during which time many of them have been required to operate on alcohol. But it is only in the last two years that the demand for greater economy and efficiency when using alcohol has been seriously felt. During 1920 we conducted some intensive studies and experimental work in the development of an engine that will burn alcohol economically and efficiently and I shall endeavor to acquaint you with a few of the fundamental requirements and with the results to be attained by their use.

Alcohol is difficult to vaporize, and hence difficult to start on. It ignites at a considerably higher temperature than gasoline, is only six-tenths as rich in heat units as gasoline by weight and 15 to 20 per cent heavier by volume. Commercial alcohol contains approximately 10 per cent of water by weight and from 10,000 to 12,000 B.t.u. per lb. Its specific gravity is from 0.80 to 0.84 at 60 deg. fahr.; its range of distillation temperatures is from 158 to 175 deg. fahr. It is a vegetable derivative. These physical characteristics are of course materially different from those of the common petroleum fuels.

We knew that higher compression was necessary, but, as engine size and design influence operation to a large extent, our first problem was to establish an approximately satisfactory compression pressure from which to start our experiments.

Our first trials were with 127-lb. gage compression at a normal operating speed.

The next problem was to determine what amount of heat applied to the mixture is desirable and its general effect on economy, output and operation. We had a real surprise when we found that more heat is needed for good operation on alcohol than is required for using kerosene.

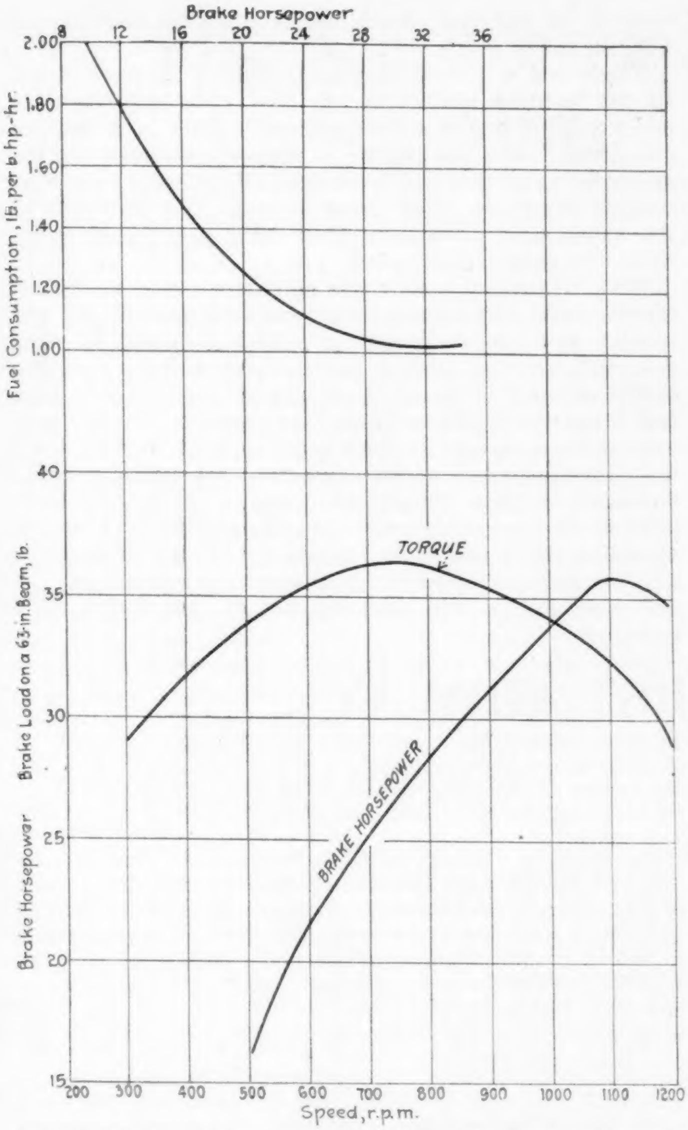
Our next concern was with the power output. This we found was equal to the power developed when using good kerosene. We then devoted ourselves to the general operation of the engine and finally the fuel consumption. At first the operation was not good at low engine speeds under sustained load and the fuel consumption was higher than we liked, but by perseverance and patience we overcame these obstacles and produced very reputable characteristics with good economy and excellent operation, using two distinct and totally different types of carbureting and manifold systems; one of which was the special Twin City Holley system worked out by our company and employed on all Twin City tractors at the present time and the other the Twin City vaporizer system which I described briefly at Ottawa Beach last summer.

As stated before, the heat value of alcohol is only 60 per cent of that of gasoline, it contains 10 per cent of water by weight, it is difficult to vaporize and requires a higher compression pressure which results in increased mechanical friction in the engine. We therefore felt that if we could obtain the same power with alcohol as with gasoline or kerosene for the same expenditure in British thermal units of fuel, we would be doing very well. As a matter of fact, we have actually attained a fair increase in thermal efficiency.

Experimental Work

Our experimental work was done on a 4¼ x 6-in four-cylinder 16-valve engine. At first no heat was applied to

[1]M. S. A. E.—Automotive engineer, Minneapolis Steel & Machinery Co., Minneapolis.

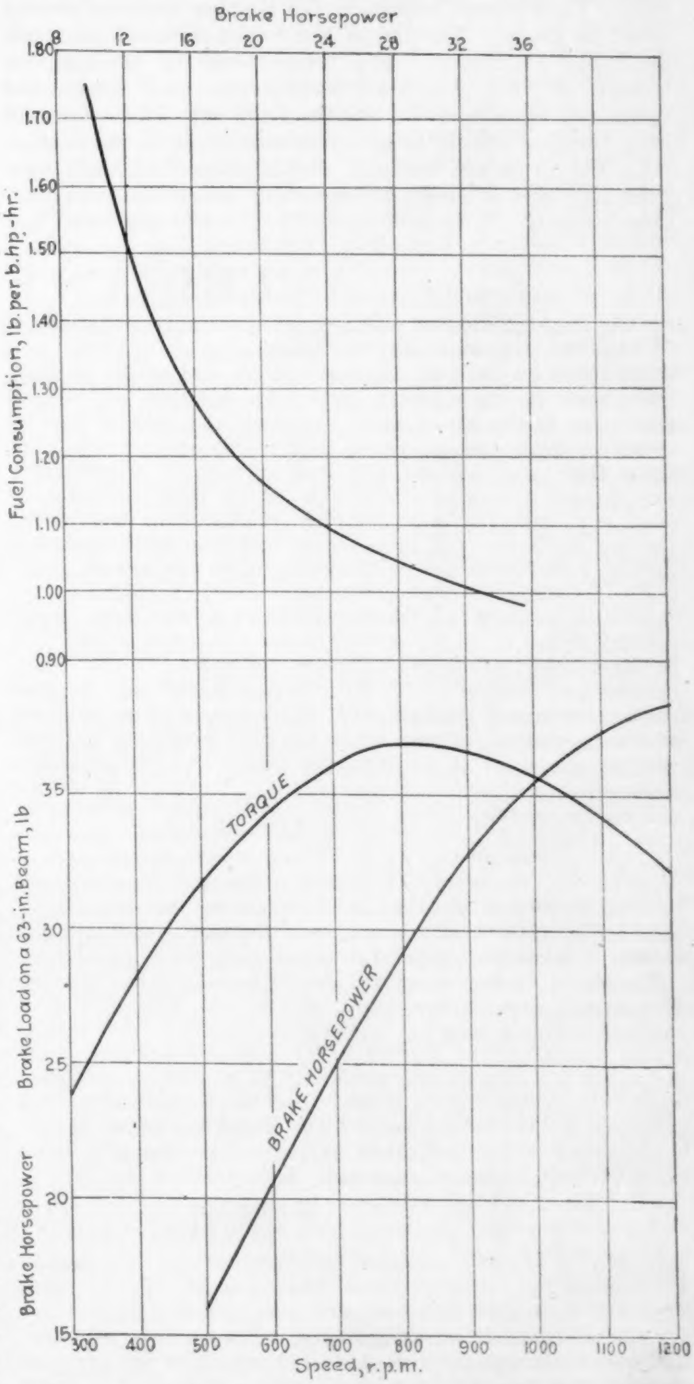


CHARACTERISTIC CURVES OF A FOUR-CYLINDER ENGINE EQUIPPED WITH A SPECIAL HOT-SPOT MANIFOLD FOR BURNING ALCOHOL

the intake manifold and we were able to develop only 29 b.hp. at 1000 r.p.m., using 127-lb. gage compression, whereas we could easily develop 35 hp. with kerosene, using 63-lb. compression. When running with a cold manifold the temperature of the intake charge dropped to 35 deg. fahr., frost collected on the manifold and water froze on certain portions of it. It was necessary to choke the carbureter to a considerable extent and very unsatisfactory operation was the result. We then applied heat with the result that the horsepower increased from 29 to 35 and operation was very much improved, although the engine would not pick up its load at low speeds.

An intake manifold with glass inserts that was used showed that a large amount of unvaporized fuel was going into the engine. We then increased the heat still more by connecting two air-heaters for the carbureter intake in series. This dried out the mixture but reduced the horsepower from 35 to 33, although the fuel consumption was decreased 1 lb. per b.hp-hr. With this set-up the inlet air to the carbureter reached a temperature of 210 deg. fahr., but after being carbureted the intake gas temperature dropped to 138 deg. fahr. with an exhaust gas temperature of 215 deg. fahr. We then decided to drop the compression pressure to 100 lb., with the result that nearly equal horsepower was developed, the fuel consumption was not increased and the operation was improved at low engine speeds.

We then tried an intermediate compression, using 110 lb., which was finally adopted as giving the most satisfactory results. With this compression we had no difficulty in obtaining an output of 35 hp., which was equal to the power developed when using kerosene. The fuel consumption at maximum load remained at 1 lb. per b.hp.-hr. The alcohol used in this experimental work contained 10,500 B.t.u. per lb. We therefore consumed 10,500 B.t.u. per b.hp-hr., which, if transposed into an equivalent gasoline consumption by weight, would show a fuel consumption of approximately 0.55 lb. per b.hp-hr.,



CHARACTERISTIC CURVES OBTAINED WITH THE SAME ENGINE WITHOUT A SPECIAL HOT-SPOT MANIFOLD

which is exactly equal to the finest performance we have obtained with this engine using gasoline and is decidedly more economical than average engine performance indicates.

The difficulties of starting are increased somewhat when using alcohol, due to the greater starting effort necessary for cranking the engine, and also because air at ordinary temperatures does not vaporize the alcohol sufficiently to make a good combustible mixture. Satisfactory starting was accomplished by a redesign of the starting-crank, coupled with the use of a mixture of four parts of alcohol to one of gasoline.

Conditions Necessary for Proper Use of Alcohol

In our case 110-lb. compression proved most satisfactory. Very liberal provision for heating the fuel charge must be made. The use of the entire exhaust heat will be found necessary. The temperature of the ingoing charge of fuel, for good carburetion and economical operation, should not be less than 100 deg. fahr. Careful consideration should be given to the design of the intake-manifold to obtain uniform distribution. At high compressions this is essential, especially when using alcohol. Gas velocity is important. The intake-manifold gas velocity, at full load, should not be less than 9500 ft. per min. on the average.

These are a few fundamental figures to work from. In our opinion alcohol is an ideal fuel, vaporizing at practically a constant temperature. This is a decided advantage; once the engine is properly warmed up, the operation is all that can be desired. Practically no carbon residue is created when using alcohol. The condition of the valves and valve-seats after long periods of heavy runs was surprisingly good.

We are thankful that it was necessary for us to do this experimental and development work with alcohol. In our opinion the use of alcohol as a fuel is bound to come eventually in the United States. We believe that the entire automotive industry should get behind this idea and bring it to pass as quickly as possible, so as to provide another source of fuel supply and to bring down the operating costs of all equipment depending now on hydrocarbon fuels. There are in the United States yearly millions of tons of unused vegetable matter from which alcohol could be profitably manufactured. If the automotive industry will demand the manufacture of alcohol for fuel purposes, it will head the list of automotive fuels eventually.

AMERICA'S FIRST AIRWAY

THE establishment of well-organized air routes throughout the country, especially in America, is as essential to a well-balanced system of national defense and as the development work on the aircraft itself. The limitless and boundless ocean of the air must be explored, and charted just as unknown lands and oceans, so that navigators can with ease make their way without any loss of time or encountering any danger across vast expanses of territory in peace or war. The installation of an airway entails the location of landing fields with all accessories, including radio direction finding, radio communication, aids to night navigation, housing and maintenance of equipment. It is undoubtedly true that with properly established airways of this kind, cross-country flying by night or day, in good weather or bad, will be safer than automobile road touring and, with the development and perfection of the machine itself, will in time surpass in speed, comfort and safety the modern comforts of transportation. These air routes will provide a network whereon the units of the National Guard and the organized Reserve can be placed. However, these highways of the air will not be usurped by the Air Service but they will be open, under legislative restrictions, to all commercial operators who will receive all the benefits and conveniences of such an organization, therefore commercial aeronautic interests will be fostered. One vital point of value in the creation of national airways is the convincing of the public that aviation control is a matter of Federal rather than State legislation.

The Model Airway which will shortly be established between Washington and Dayton, Ohio, will be the first unit in a comprehensive system of airways throughout the United States which will be started under a policy formulated by the Army Air Service and which will be guided in its organization by the experience gained from the establishment and operation of the Model Airway. The Model Airway as chosen is extremely well suited to the purpose of serving as a basic guide in this expansion program. Almost all of the natural problems attendant to successful air navigation are met on this airway, which is one that will always be needed. In the course of this route appear mountains to be passed over, varying climatic conditions, and terrain of almost every type and character.

The Army Air Service is unable of course to purchase any land or make any expenditures in connection with the creation of this airway but can provide such equipment as is available for getting the route established. The small expense attached to the installation of this route naturally should fall on those who will receive the direct benefits of its existence and operation such as the communities, organizations and individuals along the route. The Army Air Service will gladly supply all the advice, specifications and information relative to the creation of the airway. This information would pertain to such things as landing fields, radio hangars, etc., and even might include the sending of qualified officers to superintend or consult. Certain terminals on the airway will have gasoline, oil and spare parts for both Government and civilian aircraft. Charts will be made of the entire route at the request of the Army Air Service and a photographic map will also be prepared. Oblique aerial photographs of every city, landmark and landing field will be taken and arranged in such form as to provide a guide to the route. Copies of these books can be signed for at one end of the route and turned in at the end of the journey. Flyers along the route will be in constant radio communication with each other and with the various ground stations and in case of fog or clouds will be directed along the route by radio. Should a group of commercial ships that are unequipped for wireless desire to negotiate the route, then an airplane so equipped can be dispatched with them along the route and they can "follow the leader" in perfect safety. A system has been devised for marking the landing fields along the route for purposes of identification and will serve as an aid to navigation.—Air Service News Letter.

MOTOR VEHICLES PER CAPITA

FIGURES recently compiled by the American Automobile Association indicate that in the year ended Dec. 31, 1920, 8,234,490 passenger cars, 945,826 commercial vehicles and 271,230 motorcycles were registered. The gain in registration over 1919 amounted to 2,114,870, which is the greatest increase ever recorded in a single year. According to these statistics there is on the average one motor vehicle for approximately every 11 persons in the United States.

The total receipts from registrations in the year 1920 amounted to $99,141,097 or more than one-fifth of the total annual expenditure for roads and bridges in the United States. Compared with 1919 these receipts increased $34,443,842 or 53 per cent, which is the largest increase ever recorded in one year.

The Care and Maintenance of Motor Trucks

By N. J. Smith[1]

Chicago Truck and Tractor Meeting Paper

THE object of this paper is to point out some of the difficulties which present themselves in motor-truck maintenance, and to suggest, if possible, the lines along which improvement seems most needed, in order that these difficulties may be reduced to a practical minimum. Sometimes the buyer and user of a motor truck experiences disappointments due to a lack of coordination between the engineering department and sales department of the truck company. The term "service" is often misunderstood by the purchaser of the truck and misrepresented by the salesman. With the exception of a few minor adjustments, service is sold and not given, but the buyer sometimes understands from the salesman that he is to receive free service, and so a misunderstanding arises. Again, salesmen sometimes make claims and promises which are unauthorized by the factory or the engineering department, and upon which they are not prepared to make good. A dissatisfied customer is likely to be the result, because he feels that things have been misrepresented to him.

All such trouble could be avoided by a better working agreement between the factory and the sales force. Salesmen should have accurate information on the service policy of their company, and on all guarantees which they are authorized to make. Furthermore, when the prospective buyer asks questions in regard to the engineering or mechanical details, the salesman, if unequipped with accurate information, should not draw upon his imagination, as is sometimes the case, but should get the desired information from the proper source. In this way a complete understanding between the seller and the buyer would exist from the start, and the latter would know exactly what the truck is supposed to do when he places it in service. It seems to me that this question of co-operation between the engineers and the sales department is an extremely important point in the psychology of selling and buying a motor truck. The buyer must understand exactly what he is buying, what it will do and the circumstances under which it will operate properly. The salesman is the man from whom he must get most of this information. The engineer is particularly interested in turning out a truck that will run a long time in a satisfactory manner. No matter how well his truck may be built, it will not stand abuse. Consequently, he is vitally interested in having the salesman educate the customer, and in making sure that the salesman, in his eagerness to make a sale, is not losing sight of the necessity of the truck finding a good home.

The country is full of trucks running at excessive speeds in spite of a 100-per cent overload; perhaps doing work that could be performed more economically in some other way. They are left in the garage over-night and take up their work again next day without having received the proper attention to make them fit for the street. It is a hopeless task for the poor truck, and extremely difficult for the best. The result is very likely to be an early journey to the junk-heap, and a dissatisfied customer, and the cause all to often is the salesman.

While a motor truck is in the repair-shop it is a source of double expense; indirect expense due to the overhead, because it is idle and earning nothing to meet interest charges, and because of the loss of use while it is being repaired. This latter may be a cause of serious loss and inconvenience, the exact amount depending upon circumstances and being very difficult to estimate; second, direct expense for labor and repair materials. That these two items may be kept as low as possible, the truck builder must keep two things clearly in mind. First, the design of each individual part, and the material and workmanship which go into it must be the best that can be procured, in order that the breakdowns may be as infrequent as possible. Second, the assembly and coordination of the various parts into the complete truck must be accomplished with the accessibility of all these parts constantly in mind. The first of these requirements will reduce the direct expense for repair labor and materials, and the second will make possible a substantial reduction in the time required for repairs and renewals, which will mean a saving in labor and also in overhead expense. It must be kept clearly in mind that a truck in the repair-shop is an idle truck, and anything which will shorten the period of idleness promotes economy, entirely aside from the more evident saving in the mechanics' time in making repairs.

Needed Improvements in Design

I shall now endeavor to point out specifically a few points where our experience in the operation of a large fleet of motor trucks indicates that improvements are needed. Based entirely on my experience in motor-truck maintenance, I do not hesitate to say that ignition is one of the weak points in the motor truck to-day. In fact, when a service call comes in from one of our trucks on the road, we invariably send out a new magneto because we find very many times that there is where the trouble lies. This does not apply, of course, in cases where the drivers know where the trouble is, but only in cases of engine trouble, the exact nature of which the driver does not know. In other words, engine troubles are due to faulty ignition more often than to any other cause. With the possible exception of poor or inadequate lubrication there is probably no condition which contributes more to rapid engine depreciation than faulty ignition. Carbon accumulation, dilution of crankcase oil, fouled valves and spark-plugs and general irregular and faulty performance are all chargeable to poor ignition. All these conditions increase enormously the service labor and expense required to keep the truck in operation.

I believe that designers and builders of motor trucks should give serious attention to the improvement of the magneto. In the present state of the art it is possible, I think, to build a better magneto than is being used at

[1] Consumers Co., Chicago.

present on motor trucks; one that will operate for a long time with practically no attention save lubrication. It is probable, of course, that such a magneto would be more expensive than the present equipment, but intelligent users of motor trucks would be glad to pay the increased cost if assured of a better device. Operating savings, due to the elimination of the many ills which follow poor ignition, will repay them many times over for the increased cost of the better magneto. The breaker-box and platinum points give a great deal of trouble. Would it not be possible to make a dirtproof breaker-box?

There are a number of fairly good carbureters on the market, and others not so good. In my opinion, the gasoline engine has by no means reached the end of its development, particularly along the line of efficient use of fuel, which is largely a carburetion problem. When 25 to 40 per cent of all the heat in the fuel is contained in the exhaust gases, in the form of unburned or partly burned gasoline, it would appear that there is room for improvement. I believe that this improvement can be brought about to a considerable extent at least through a better control, over a wider range, of the proportions and the temperature of the fuel mixture. This control must be automatically governed by the load demands on the engine in the interest of both power and economy.

While we await the advent of more efficient carburetion equipment, the present carbureter should receive a little attention from the designer. It should be made as nearly foolproof as possible; adjustments must be few and simple, approaching automatic operation. More attention must be given to the effect of vibration on the operation of a carbureter. Leaky floats and valves often caused by vibration are wasteful of fuel and constitute a fire hazard. Furthermore, needle-valves and seats poorly designed or imperfectly made are a frequent cause of annoyance and delays.

I believe it is the general consensus of opinion among motor-truck builders that a reliable and efficient governor is highly desirable. Because of the rapid depreciation caused by high speed, the life of engine and truck depends to a considerable extent on the efficiency of the governor. Our experience with governors is that very few of them function properly. They require almost constant attention to keep them in working order and if they are neglected the engine will soon be running wild. The average driver likes speed and cares little about truck depreciation. A governor must be simple in design and of the very best construction as to materials and workmanship. A better means than is now available for sealing the governor should be devised. It seems to me that a lock should be used, having a key which the owner or the garage superintendent can retain in his possession. This will tend to assure proper operating speeds, which are an excellent insurance against engine troubles.

Lubrication of the moving parts on the chassis is usually taken care of by the installation of grease-cups. In principle at least such a provision should be ample, but in practice the user of the truck frequently finds that the results are not satisfactory. If the filling and turning down of the cups is made a part of the driver's duties, it is almost certain that it will be neglected. I believe that fully 75 per cent of the trucks on the street are insufficiently or improperly lubricated, largely due to the fact that the driver neglects this important duty. We find from our experience that it is much better to have the greasing of the trucks done in our garage, at regular intervals, by service men assigned to this particular duty. In this way the work is more systematically done and results are much more satisfactory. But even with this system a grease-cup will occasionally be neglected or overlooked, especially if it is located in an inaccessible position.

The design of grease-cups leaves much to be desired from the point of view of the maintenance man. They are generally cheap stampings with coarse threads. The threads are very often crossed when endeavoring to fill and replace the cups in some inaccessible place, and as a result the cup is ruined. Constant vibration frequently jars a grease-cup loose, and once it is lost it is seldom replaced. It seems to me that if a grease-cup could be developed along the lines of the self-feeding compression type, lubrication would be much more efficient and maintenance expense materially reduced. If such a cup were developed, it would probably be necessary to use greater care in selecting a lubricant properly adapted to the weather and temperature conditions under which the truck operates. But this can be taken care of by the garage or service department, and need constitute no valid objection to a substantially automatic grease-cup, if one can be designed by the builders' engineers.

My experience indicates that attention should be given to the equipping of truck wheels with non-skid devices for operating in mud, snow, or ice. Many builders make no provision for any such device; others have made attempts, but I know of no successful solution of this important point. I have sent out trucks in the morning equipped with six chains on each rear wheel; at night they have come back with only one chain left. These chains are very hard on tires and springs, and impose serious strains on worm-gear drive-axles. The builder who can solve this important problem will make a valuable contribution to the motor-truck industry.

In connection with the above, I believe that some serious thought should be given to the question of cushion wheels. I am not prepared to make suggestions on this point, but believe that a good cushion wheel is much to be desired.

A motor truck is a compact, highly specialized piece of machinery, and when the final assembly is complete it is almost inevitable that some of the parts should be extremely difficult to get at. To save time in making repairs and renewals, all parts which, from their nature are most likely to need attention, must be readily accessible. Among these parts, the engine, transmission, magneto, water-pump and grease-cups may be mentioned.

The engine should be installed in such a way that it can be readily taken down for repairs. We have trucks from which the entire engine can be removed by two men in $1\frac{1}{2}$ hr., and we have others which would require three times as much labor for the same job. Some engines are built so that the bottom half of the crank-case is readily removable, providing access to crankshaft and main and connecting-rod bearings with a minimum of labor. This is important, because as every maintenance man knows, the labor of taking down an engine and reassembling it after the repairs are made, is often the largest part of the job.

The above considerations in regard to engines apply to transmissions also. From our experience it seems that very few builders using a transmission amidships make any provision for filling or inspecting it except through the top. If any other than a dumping body is placed on the chassis the transmission is inaccessible, and if something goes wrong the body must be removed to get at it.

As pointed out earlier in this paper the magneto is a frequent source of trouble and must be repaired or re-

placed. Consequently, it must be readily accessible, and also the shaft or other means of driving it. The removal of the magneto necessitates disconnecting it from the shaft, a difficult job in an inaccessible place.

Frequently the water-pump is placed in such a position that replacing becomes extremely difficult. Both the pump and the magneto may be driven from the same shaft, located where it is readily accessible from end to end. Some designs place this shaft in a transverse position in front of the engine, which in general provides greater accessibility than when it is placed in a fore-and-aft position by the side of the engine.

A grease-cup located where it cannot be reached readily is little better than no cup at all. I believe that until automatic grease-cups are devised, motor-truck builders should do everything in their power to design their machines so that the grease-cups are easy to reach, and replacing, filling and screwing down can be done with a minimum of time and labor.

Maintenance Practice

I have been asked to speak also of the care and maintenance of motor trucks. This is rather a wide subject, and I feel that I shall be telling some of you things that you already know. The Consumers Co. operates 159 motor trucks, which cover the entire city of Chicago and the outlying districts, and each day are delivering coal, ice and other supplies. Keeping these trucks on the road and cutting down expenses or making the maximum haul at a minimum cost is my job. Naturally, in the pursuance of this work, we are always on the lookout for every possible place at which we can effect a saving. It has been our experience, as I will tell you, that in no place is the expenditure of money more justified, or does it bring greater return, than in keeping our fleet *away* from repairs. I mean by this, treating all our equipment with such inspection and nightly adjustment that it is kept constantly up to a high level of mechanical efficiency. This means, to be exact, that as little time as possible is spent in the garage, or out of active work. I will show you how we have formed our organization to bring this about. I shall not go into details over the truck on the road, the routing, or the means by which we keep in touch with our equipment while it is moving. The modern loading and unloading devices have already shown their efficiency, so I shall not speak about them other than to mention that in our larger yards we load by overhead locomotive cranes that are capable of loading from 2 to 10 tons in 2 min. The time taken for our trucks to get into the yard, get their load and out again is usually under 5 min. As some of our trucks make us as much as $1.20 per ton, you can readily see our anxiety to keep them moving. A truck standing still earns no money.

What I do want to talk about is our garage and shop equipment. Here is the power behind the throne. This is where the trucks are kept fit. It is here that the very backbone of our system is kept nourished. Without proper maintenance, a truck cannot bring in the profit that it should. "All the trucks on the road all the time" is our motto; we try to live up to it. Here is where we differ from the modern acceptance of repairs, "the chief part of maintenance," as some put it. He is a poor doctor who will let his patient get into such a condition that the only thing which will save him is an operation. It is just as poor policy to let the first attention you give a truck ailment be a repair. Then the damage is already done and your truck will suffer forever afterward as a result; no matter what reparation you make to the injured part. It is the ounce of prevention that pays. Let me emphasize this statement strongly. Nearly all our energies are devoted to keeping the trucks from ever getting into such shape that they will need overhauling. Does it pay? It does. We have some trucks that have gone over 70,000 miles and are, as near as we can tell, in as good a condition as the day we bought them from their builder. There are some that are more than 4 years old, and show no evidence of wear. Does this speak for the wisdom of our system?

Trucks on the road are constantly under a stress and strain. This tends to make their lives shorter than any other kind of transportation machinery. It is this depreciation that we fight. In prolonging a truck's life we reduce our cost per mile of haul with that truck. We have not effected these results without expense. Some of the items of cost have been fairly high and were some time in proving their value, but we are reaping the crop now. I do not think that you will consider it boasting if I say that I think we are delivering coal and ice cheaper than anyone else in the city of Chicago.

Our garages have been the subject of great care and thought. Much of our work is done at night. We have built the garages with an eye to two results; fast work and good work. Here is where these trucks are washed and inspected each night, and I might say that each truck gets this each night. Clean floors and walls of fireproof construction add to the appearance and reduce our fire risks. All inflammable gases are taken out through the wall construction. There are plenty of windows for pure air and there are few shadows. Also there are no columns to get in the way of truck or man. The floors are stripped for action. You must remember that we have over 159 trucks and each one of these has to receive an inspection, a wash and a general cleaning every night in the year. This inspection is nothing in the way of a casual "once over," but a careful looking over of each truck as it is checked in at night. By keeping our floors clean and well drained, our men are able to wash a much larger number of trucks than they would in the same time on a floor with bad drainage. Our washing and draining systems are arranged so that it is possible, in case of necessity, to wash any truck wherever it stands in the building. Our rule, however, is to have all trucks sent to the special washing floor. This floor is free from shadows as it can be. This gives the man ability to see his work so that he can get it done faster and better.

Our plumbing system is arranged for both hot and cold water. Steam boilers keep the soap and water as well as the suds at the correct temperature at all times during the washing period. This was a large expense in plumbing, but a huge saving in labor cost is the result. To avoid sewer stoppage we have large catch-basins. These are cleaned every 7 days. As tons of dust are washed out of the trucks, care is exercised to keep this from getting into these basins. The floors are cleaned with large scrapers built so that one man can handle them. This done, the floors are washed, and this is done every day. You will probably think that I am spending a long time getting my subject cleaned, but it is necessary, for now we come to the inspection. Much of the cleaning is done to bare the surface of all the truck and its mechanism so that the inspector can see if there is anything wrong. A hundredth of an inch of coal dust can cover up a multitude of troubles.

Our inspectors have good eyesight. If through laziness they become blind, they also fall heir to another position. The mechanics go over the truck every night,

tightening brake-bands, straightening mud-guards and checking up on all the little things that may go wrong with the truck, and catching these flaws before they develop into serious troubles. Back of them all are the inspector and his assistant. The driver's trouble card has already eliminated any truck that has shown any minor or major trouble, and it is these trucks *apparently in good condition* that the inspector searches through to find the trouble that is brewing. That is where the ounce of prevention comes in. This inspector and his assistants cover all the trucks once every month. Not one single part being overlooked. This man has a printed form covering all parts of the truck. The inspector covers the engine in detail; the spark-plugs are adjusted and the compression of each cylinder is taken. In this way we are better able to tell when the cylinder needs regrinding. The transmission is gone over to determine the condition of the gears and if necessary filled with grease to the proper level; the clutch is carefully tested; universal-joints are Alemite equipped which saves much time in filling; and we never find one dry. The wheels are taken off and bearing cups and cones are cleaned and gone over carefully for worn or defective parts. Before assembling a fresh supply of grease is put into wheels, and the bearings very carefully adjusted. Since installing this system of looking after the bearings our wheel bearing trouble on the street has disappeared. All grease-cups are checked up to see if the men doing this work are doing it efficiently. The cooling system is closely checked. Rear ends and tires are checked up and their condition reported. The hoist and body are also covered. It may interest you to know that it costs as much to maintain one of these dump bodies with hoist per year as it does to maintain all the rest of the truck. This inspector's card shows also whether the engine is being kept clean, if the truck is being washed; everything must be in perfect shape or reported for repairs, so when this card is turned into the office it shows the mechanical condition and appearance of the truck. If you had a passenger car would you like it to get this treatment every month? Would it pay you?

Now comes the slippery subject of greasing and oiling. Just as we have one man to wash from 12 to 15 trucks, we have one man whose sole aim in life is the greasing every night of from 15 to 18 trucks. That is his job and on the proper performance of his job rests to a great extent the proper performance of our trucks. I will give you an example. How many operators pay any attention to springs? Practically none that I can think of. With us this is an important item. Every spring is washed down with waste oil. As a consequence we have practically no spring trouble; and this in face of the fact that the majority of our equipment is of 7½-ton size carrying a 33-per cent overload day-in and day-out. When we take a truck down for overhauling, we invariably find the spring leaves well separated, with no rust present and lots of grease worked through. Under similar conditions, on most trucks you will find spring leaves frozen together into a solid mass of rust and metal. Such a spring lacks resiliency. This means a saving that is hidden at first thought, the saving on tires.

Handling Repairs

Sometimes, strange as it may seem, even our trucks will get out of order. In other words, they will not run. If this happens on the road, we send a service car to make the truck run or tow it in. We do not allow our trucks to "limp" in.

Minor repairs are made by mechanics capable of doing almost any kind of a job with a reasonable amount of speed and accuracy. This is done at the garage during the night. Jobs that consume several hours or more are listed for the shop. This shop is always in the hands of an experienced man. In laying out the building special attention was paid to ideal working conditions and making the men happy; good light and ventilation mean good work.

In the selection of tools and equipment, a study is made of each individual operation to find the best means of handling it. If after a careful analysis is made, it is found that tools or machinery will make a saving, these are installed. Without great care in the selection of machinery and tools it is an easy matter to fill up valuable space with machinery that will not pay the interest on the investment. Our shop equipment consists of shaping and milling machines, air hammers, drilling machines, drop hammers, special reamers for all bearings, woodworking machines and machines for painting. As we have been able to standardize our automobile equipment to a great extent, we are able to save in shop equipment as well as in our stock of parts. This is an example of standardization. Our machinery equipment is laid out on the floor of our shop so that repairs can be routed through in the most efficient manner, thus saving the time of rehandling and doubling back to the same men.

From our stock records we are able to know just what parts we are likely to use in our garages during the night. Having this knowledge eliminates carrying all unnecessary parts, thus saving a large sum of money and time in keeping the record of these parts. The main stockroom is connected with our shop and carries everything that goes into the truck. Our garage stockrooms draw on this one for all parts. The shop has on hand at all times an extra engine ready to go into a truck in case one comes in with trouble that would necessitate taking the engine out. The extra engine is put into the truck while the one taken out is repaired and put into stock prepared for a similar case. This liberates an investment of some $8,000 to keep on with its work of earning money for us. We have extra electric motors and batteries for the electric trucks, extra wheels for both gasoline and electric trucks and complete steering posts; in fact any unit that our experience has taught us will save time and keep our trucks moving at all times. Our stockroom is arranged for keeping a perpetual inventory. There is no kind of job on a truck that cannot be handled in this shop.

All our men are most carefully selected. We treat them well and they know it. There is always a waiting list of applicants; by having a quantity to pick from we get a good type of man. There are factors in human nature that work against efficient organization and there are those that work strongly for it. Pride and contentment are our aids; and these we try to build up in our own men.

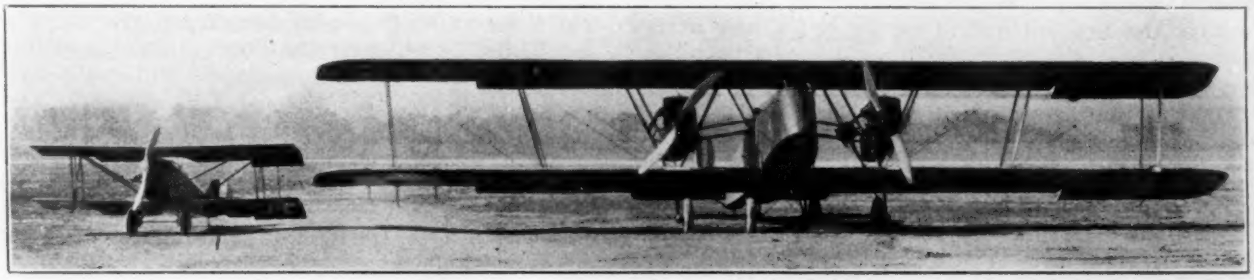
Perhaps what I have said today has not been efficiently specific. It may be that I have attempted to cover too much ground. I hope not. It is quite possible that some of you will think that we have built up too big an overhead for our equipment. I can only assure you that I have given you the honest result of our experiments and experience. It is more economical to spend money in the prevention of trouble than it is to let the opportunities for saving slide by, gamble against the law of averages, and then, in the end, pay the same amount of money and more to repair defects.

Recent Progress in Military Aviation

By Major H. S. Martin,[1] U. S. A.

Annual Meeting Address *Illustrated with* Photographs

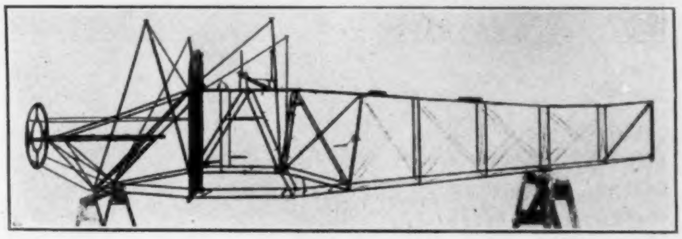
With the time available it is possible to give only a brief outline of my subject, and much of importance will be neglected. I will endeavor to give in a few words an idea of recent progress by the Engineering Division with its diversified problem of the development of all heavier-than-air equipment for the Army Air Service. Briefly stated this problem includes the development of the 15 types of airplanes, embracing those for pursuit, attack, observation, bombing and training, at present believed necessary to fill Air Service requirements. When we consider that a military airplane carries from 1000 to 20,000 lb. of crew with oxygen, parachutes, other conveniences or necessities, fuel and oil, machine-guns, cannon, ammunition, sights and instruments of various kinds, bombs, photographic and radio equipment, a total distance of 300 to 1000 miles or more, and at a speed of from 100 to 180 or 190 m.p.h., and that



The Verville Messenger and the Martin Night-Bombing Airplanes

the engine, all armament and equipment must operate or be operated satisfactorily at air temperatures varying from 100 deg. above to 50 deg. below zero, fahr., and in all weather conditions, the diversity of the problems encountered will be appreciated.

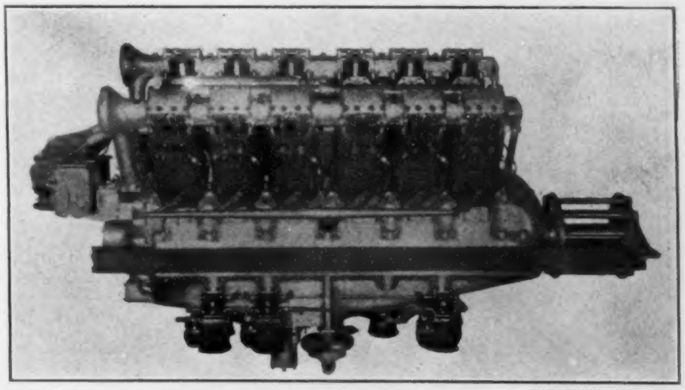
It is usually most convenient in a discussion to consider the complete airplane under the heading of the airplane proper, the powerplant, the armament and the equipment. The airplane proper is perhaps the least of our troubles. We are able to build airplanes strong enough, and thanks largely to the engines available we are rarely obliged to discard an experimental airplane because of poor performance. This, of course, does not mean that performances cannot be considerably improved. However, the installation of all that goes into an airplane is rarely accomplished to our complete satisfaction. It is a very difficult job and remains to be done in making satisfactory installations of engine, armament and equipment. The Fokker D VII with the Packard engine is an engine installation that provides sufficient strength and rigidity, and at the same time the engine is accessible, which means much to those responsible for keep-



The Steel-Tubing Framework for the Fuselage of a Night-Pursuit Airplane

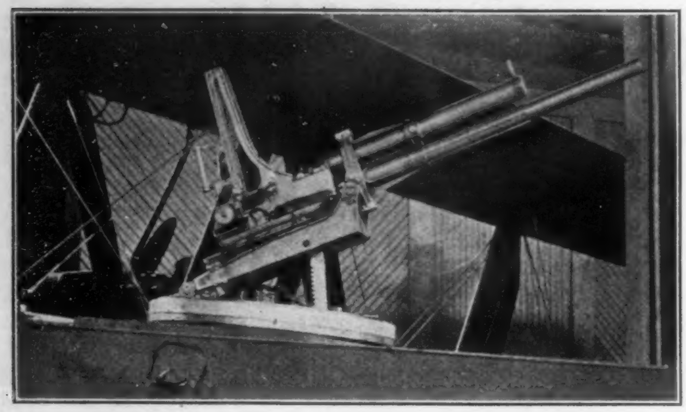
ing airplanes in commission. It is a neat installation that is not compatible with simplicity. The Verville Packard Racer shows a leaning toward the other extreme. This is not a strictly fair comparison since this airplane was not originally designed for the engine.

Going to one or two of the types at present considered to fill Air Service requirements, we have the Thomas Morse MB-3, a single-seater pursuit airplane with the 300-hp. Wright engine. Some of these airplanes will soon be in service on the Border. The G. L. Martin Co. MB-2 is a short-distance night-bombing airplane with two



The Type W 700-Hp. Engine Which Has Been Developed by the Engineering Division of the Air Service

[1] Engineering division, Air Service, McCook Field, Ohio.



THE 37-MM. CANNON MOUNTED IN AN AIRPLANE

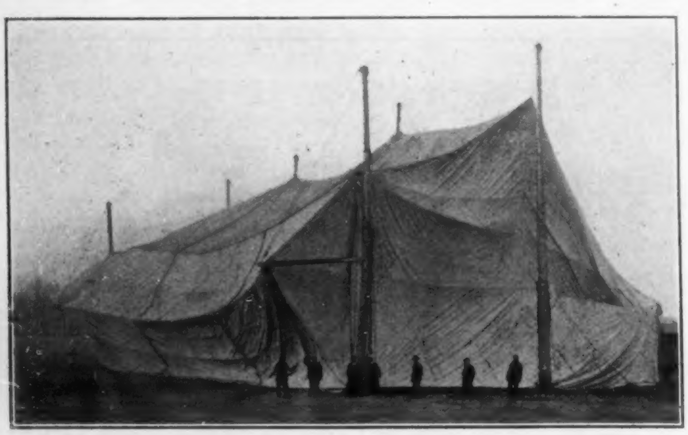
Liberty 12-cylinder engines. This airplane is a development of the Martin bombing airplane originally delivered to the Air Service in 1918. The small airplane shown in front of the Martin bombing airplane is the Verville Messenger. This airplane was built by the Lawrence Sperry Aircraft Co. in accordance with a design furnished by the Engineering Division. The original idea was an airplane for messenger work, but it is possible that it may be of use for training.

For night pursuit we have a recent acquisition in the Curtiss Co.'s NP-1 airplane with the Liberty six-cylinder engine. This airplane is still experimental, having just completed its static test. The construction of the fuselage is of steel tubing.

Perhaps the best method of laying out a new design is that requiring a mockup which is a model true to size of an airplane with the engine and all armament and equipment installed. In this way the clearances, location of armament and equipment and engine installation can be studied and corrected far better than by drawings.

DEVELOPMENT OF ENGINES

Going to the question of engine development, our first task has been to develop existing engines, especially the Liberty 12-cylinder type and Wright 180 and 300-hp. units. The Liberty engine has been fitted with inverted carbureters which have improved the operation and are at the same time much more accessible for adjustment. The altitude control has been improved and made effective at higher altitudes. The Wright 300-hp. engine has been fitted with inclined magneto brackets, making a simpler engine-bed possible and eliminating the necessity for right and left-hand magnetos.



A LARGE CANVAS HANGAR CAPABLE OF HOUSING THREE MARTIN BOMBING AIRPLANES

Very many engine tests have been conducted with a view to improving engine performance. With anti-knock fuel and high-compression pistons consumptions lower than 0.45 lb. per b.hp.-hr., in one case 0.42 lb., have been observed. This places aviation engines on a footing with the best Diesel engines as regards fuel consumption per delivered horsepower-hour. A large number of single-cylinder tests have been made of air and water-cooled engines under construction or being considered for production. One test of a $5\frac{1}{2}$ x $6\frac{1}{2}$-in. water-cooled cylinder with four spark-plugs showing an increase in power, but the gain in using more than two plugs is probably not worth the added complication. The General Electric supercharger for the Liberty engine, with the variable-pitch propeller, is being given flight tests. Steps have been taken to develop a supercharger for the Wright 300-hp. engine. We also propose letting a contract for a gear-driven supercharger.

Our work in the development of new types has been largely concentrated on large water-cooled engines and air-cooled radial engines of from 60 to 350 hp. The 700-hp. Model W engine designed by the Engineering Division, which is now starting its first run, is shown. A reduction gear for the engine has been designed and will be constructed.

The preliminary design of a 1000-hp. 18-cylinder engine is completed and work is progressing on the complete design. The Packard series, an eight-cylinder for training, a small 12 for pursuit airplanes and a large 12 for bombardment types, have completed their tests. The large 12 is the engine installed in the Verville Packard Racer. Additional small orders have been placed for these engines with modifications. It is proposed to increase somewhat the size and horsepower of the small 12-cylinder unit. The Wright cannon engine is being modified as a result of its tests and we hope to have soon a satisfactory engine for the 37-mm. cannon.

The radial air-cooled types are being covered by the Lawrence 140 to 160-hp. for training airplanes, and the 350-hp. Weinberg and the Wright engines for service types. The Wright engine has started running, the Weinberg is being prepared for its preliminary tests and we hope to have the Lawrence soon.

For a radial water-cooled engine we have under consideration one of the barrel type known as the Almen engine. This engine will permit a cannon to be fired through the crankshaft, and in addition an engine of this type of 350-hp. would have a diameter of about 18-in. and a length of about 36-in. This feature of compactness is of course a great advantage. While the general idea is not new, it is believed the present model offers a chance of success, and its advantages justify the expenditure of some time and money.

PROBLEMS OF ARMAMENT DEVELOPMENT

Passing to armament development, the main problems are to mount the fixed and flexible machine-guns and cannon of varying calibres so as to provide for the satisfactory feeding of the ammunition and the ejection of the empty shells, to provide for the synchronization of the fixed guns and to provide for carrying bombs. We endeavor to provide for interchangeability of the various types of machine-gun. It should be explained that the Ordnance Department of the Army manufactures the machine-guns, cannon and bombs used by the Air Service.

The location of fixed guns has been confined to rather

PHOTOGRAPH OF A FOREST FIRE TAKEN FROM ONE OF THE AIRPLANES OF THE FOREST PATROL

narrow limits because they are synchronized by a device driven by the engine, usually by mechanical means. With the development of the electrical synchronizer the problem will be greatly simplified, since wires are more easily located than tubes, rods or cables. In mounting flexible guns three of the requisites are field of fire, ease in operation and rapidity of fire. The field of fire is somewhat dependent on the design of the airplane, but a new mount has been developed which increases the field of fire and is reasonably easy to operate. To assist the observer or gunner in handling the guns, a wind compensator for the flexible mount has been designed and constructed. The force required to move two guns as well as oneself against a wind blast of from 125 to 150 m.p.h. would ordinarily

TYPICAL COUNTRY COVERED BY THE AIRPLANE FOREST PATROL

be underestimated, and the compensator is designed to assist the operator by means of springs.

For securing volume of fire, a mount to carry four Lewis guns has been constructed. To take advantage of the rapidity of fire of the Browning it has been mounted flexibly. This has necessitated designing a reel for the ammunition similar in purpose to the Lewis gun magazine. The 37-mm. cannon has been mounted in almost every conceivable position in the airplane where it would be of any use. The 2.95 mountain gun has been mounted and fired from the Martin bombing machine.

Equipment Development

Equipment development has been confined largely to crash and leakproof tanks, parachutes, hangars, take-off mats and cameras. Work has been done on navigation instruments and the use of radio for navigation. One instrument deserving mention is the universal gasoline gage which will go in any tank from 10 to 50-in. in diameter, and also permits some choice in the location of the dial.

Crashproof is a term applied to tanks designed to prevent gasoline spilling all over the engine, with fire resulting, in a crash which often splits the tank. The tanks are of the usual construction except that they are covered with a thin bag of live rubber. Experiments show that this is an advantage.

The development of leakproof tanks is being continued but the advances in the armament of airplanes with heavier calibres and more destructive ammunition will apparently require a new and different solution before long.

Satisfactory parachutes of the back, seat and lap type have been developed, and some are in use. The back type will probably be used for training, while the seat and lap types will be used for service. The latter types are somewhat smaller and better suited for service because of this, and also because they interfere less with the operations of the pilot, observers and others. In an attempt to get the parachute entirely out of the airplane, and yet avoid the disadvantages of the type attached to the airplane, we recently experimented with what is termed the detachable parachute fuselage. The parachute is carried in the rear of the fuselage and in case of accident the pilot pulls a lever disconnecting himself and the rear of the fuselage.

The technical development of radio is under the direction of the Signal Corps of the Army, the Air Service making service tests only. One phase of these tests is an automobile equipped with radio with which it is possible to keep in communication with an airplane, while the automobile is running along the road.

The development of hangars is a difficult problem. The effort to make them easy to erect, take down and transport, and yet withstand all weather conditions results in something of a compromise. One recently constructed by the Henrix Leubert Co. which is perhaps the largest canvas hangar yet constructed and will house three Martin bombing machines is shown.

To enable airplanes to take-off in muddy fields we are developing so-called take-off mats. Although it might appear a relatively simple matter, it is very difficult to provide 300 or 400 ft. of a satisfactory width to stand up under rough treatment, and yet not require too much in the way of trucks to transport it. At present there are two types, one a rope net with canvas, the other a canvas mat with hickory slats.

The Forest Patrol furnishes excellent opportunities for service tests of aviation material, and at the same time is doing a great amount of good. Under the direction of Col. H. H. Arnold, this patrol has been operating over the States of California and Oregon. From about the middle of May until the end of September the six stations made over 1200 patrols for a duration of 4000 hr., and over 1600 fires were located and reported. In this flying time there were 41 forced landings, or one to about every 100 hr. of flying, or one to about 30 flights. It is interesting to note that the station flying the greatest time had no forced landings. Since the equipment was substantially the same this shows the possibilities in properly taking care of equipment, although other conditions enter. Notwithstanding the character of the territory flown over, as shown by the illustrations, there was only one fatal accident.

FEDERAL HIGHWAY COMMISSION URGED

After a careful survey of the highway question I feel that the best way to focus the attention of the public on this great problem, is through the creation of a Federal Highway Commission, which should take over the work of the present Bureau of Public Roads, and I say that without the slightest criticism of the men in charge now who are doing all that they can under the limitations of the present law. If a commission of five men could be appointed by the president with the advice and consent of the Senate, several results would be obtained at one stroke. In the first place, highways would be given their proper place as the most important single domestic phase of the Government work. Not only would the recognition be a proper one, but it would serve to stimulate the interest of the students in college, to whom we must look for our future corps of trained men to handle the vast expenditures now available and to be made in the future. We would have a body of men in charge of the work whose duty it would be to look at the question from a national rather than a sectional viewpoint, although their selection from varying geographical centers and cooperation with State highway departments would insure the latter against any neglect of local conditions. Instead of the possibility of a change in policy such as is always possible where the administration changes each four years, we would have a continuing policy, as these men would be appointed in rotating years, thus keeping at the head men constantly informed as to the work at hand.

Any men selected should be big, mentally. They should be selected because of their knowledge of the subject rather than from a political standpoint, and to present a rounded viewpoint, they should include engineering, industrial and agricultural minds, although not necessarily men engaged in those occupations at the moment. These men could then sit down and with State officials could shape a national policy which would take into account national as well as State needs. Their report to Congress would naturally give us the basis for the soundest possible national policy and one that would insure the wisest expenditure of funds.

The actual construction work should always be undertaken by the State departments under Government supervision, where the State departments have the power and ability to do so. The present regional districts should be retained and every effort made to avoid duplication and overlapping since any upbuilding of national construction forces where State organizations are effective, would defeat the very purposes in mind. Present experience points to a concentration of national funds on a selected national system which should be built and maintained at Government expense.—Edward S. Jordan of the Highways Committee of the National Automobile Chamber of Commerce.

Investigations of Road Subgrades

By A. T. Goldbeck[1]

Annual Meeting Paper *Illustrated with* Charts and Drawing

ALTHOUGH road engineers have long realized the necessity for properly supporting the road surface, only in the past few years has there been a more general recognition of the value of a close study of the subgrades of roads. Let us review some of the conditions that have forced upon us the desirability of looking into the subgrade; then we shall have a better understanding of just what we mean when we speak of the "subgrade problem."

When traffic loads were comparatively light, little trouble, except in isolated cases, was experienced with the failure of the surface to support the load, but as motor trucks have become heavier and heavier numerous cases of road failures are reported from various sections of the country. In some cases these failures are so frequent and so general as to interfere seriously with the serviceability of the road and its entire reconstruction has had to be undertaken after only a few years of service.

Just what do we mean by a subgrade failure of a road and what are the conditions that bring it about? Our higher types of road such as are used for motor-truck traffic are not capable of much distortion without cracking or weakening of the road structure. If the strength of the road slab as supported by the underlying subgrade is insufficient to prevent undue distortion under the heavy concentrated wheel loads of trucks, failure of the surface results through the cracking of the slab, and if the subgrade is very soft little time is required for heavy traffic to break up the surface completely and churn it with the underlying mud. Pavements having little or no slab strength will likewise suffer from undue distortion and soon break up under traffic when the subgrade is soft. In many cases, although the incipient failure has produced cracks or serious distortion of the pavement, the final failure may not take place immediately, but the pavement is placed in such a condition as to involve high yearly maintenance expense. If the road surfaces are adequately supported to prevent undue distortion under heavy loads, we should have very few complete and rapid structural failures of roads; they would then fail only after long periods of service through gradual surface wear and disintegration.

The problem of the subgrade is evidently that of finding what causes certain kinds of subgrade material to be soft and of very low bearing value and, having discovered this, to determine what means must be employed to either remedy the condition of the subgrade or fit the design of the road surface to the subgrade. Let us go into the matter a little further and consider something of the mechanics of the problem. Then let us think about some of the various factors involved in producing an unstable condition in the subgrade. First, what happens

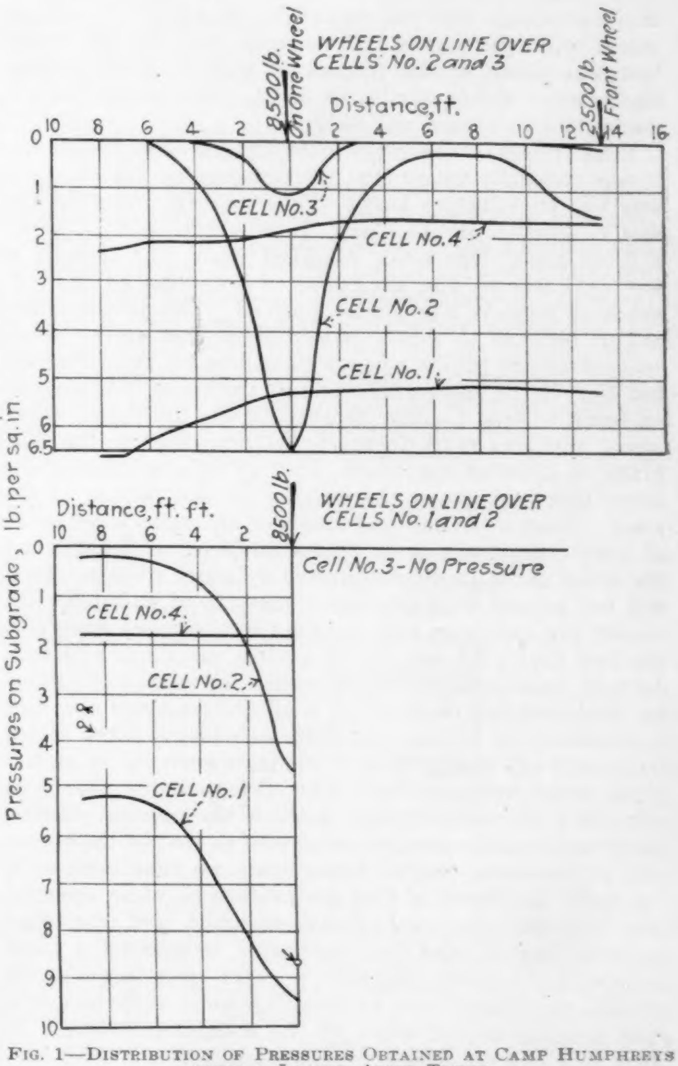


Fig. 1—Distribution of Pressures Obtained at Camp Humphreys with a Loaded Army Truck

to the subgrade when it is called upon to support the extremely heavy wheel concentrations of our large trucks? Let us assume that a high type of road having a wearing surface suitable for heavy traffic has been laid on a subgrade of uniform quality and that a heavy truck is at rest on the road surface. Under each wheel there is exceedingly heavy pressure and all of this pressure is necessarily transmitted to the underlying subgrade. The manner in which pressures are transmitted has been given practically no thought and is a subject very little understood by engineers. We have succeeded in gaining some information on this matter with the use of a special cell for measuring soil pressures, which depends in

[1] Engineer, Bureau of Public Roads, Washington.

principle upon the balancing of the soil pressure with air pressure within the cell and noting the air pressure required for this purpose. This device has been described in a previous paper.[2]

Tests at Camp Humphreys

Some few years ago a test was made on the Camp Humphreys concrete road in which the pressure distribution was determined under each wheel load. The intensity of pressure on the subgrade is shown in Fig. 1. It will be noticed that the highest intensity of pressure occurs directly under the wheel and that the pressure diminishes according to a curve and disappears about 6 ft. away from the wheel. It will be seen also that in this particular test the maximum intensity of pressure was $6\frac{1}{2}$ lb. per sq. in. A complete description of this test was given in the Bureau of Public Roads publication, *Public Roads*, for April, 1919. The wheel-load producing this pressure was 8500 lb.

Similar tests were made with lighter wheel-loads and it was naturally found that the pressure on the subgrade was less with lighter loads. Very recently a similar test was conducted on the Camp Humphreys road in which a 5-ton truck was used, designed with four instead of two rear wheels, and the curve of pressures on the subgrade as given in Fig. 2 was obtained. This is very interesting because it shows immediately that heavy wheel concentrations produce heavy pressures on the subgrade, but that if the same gross load of the truck is supported on more wheels, thereby decreasing the individual wheel loads, the maximum intensity of pressure on the subgrade is likewise decreased; and, as will be pointed out later, this may mean the success or the failure of the road. Tractor trucks and the use of trailers would be of great advantage from this standpoint at least, since the large gross loads are carried by more wheels. Time will not permit of a detailed discussion of this test; the results are indicated here to point out to truck designers the fact that they can aid in saving our roads and incidentally make available more money for new construction by whole-hearted cooperation with the road engineer and a consideration of the possibility of designing the motor truck with the idea in view of ultimate economy of motor-truck transportation, and with the thought clearly in mind that ultimate economy involves the economy of road construction and maintenance as well as that of the operation of the motor truck. Other tests we have been making point so clearly to the desirability of close cooperation between the motor-truck designer and the road engineer that I have felt warranted in making a brief digression from my subject. I refer to a large series of tests that have been showing us some surprising results bearing on the effect of the weight and design of truck and tire equipment on the impact on the road surface.

The curves of pressure shown in Fig. 3 apply, of course, to only one particular case, that of an 8-ft. concrete road supported on a rather wet subgrade of poor supporting value. It will be readily understood that if the concrete slab had been of different thickness or if the subgrade material had been harder or softer, the curves of pressure would have had somewhat different values, although the general relations shown by these curves would have remained practically the same. It will likewise be understood that a pavement with slab strength is more likely to distribute the heavy loads over a wider area on the subgrade than pavements having no slab strength, and that at the same time the maximum intensity of pressure under such pavements would be smaller than that under a pavement of the latter type if the thickness of the two pavements were the same. A pavement having no slab strength can be made to distribute heavy wheel concentrations to the subgrade, however, by merely increasing its thickness. We have seen in the tests just cited that the maximum intensity of pressure on the subgrade due to a wheel load of only 8500 lb. is equal to $6\frac{1}{2}$ lb. per sq. in. This seems like a very small pressure, but even this pressure is very much more than some subgrades are able to support, and this is by no means the highest pressure to which the subgrade may be subjected, for some pavements must carry wheel loads of 15,000 lb., not at rest but moving and therefore applied with impact.

Soft Subgrades

Suppose the subgrade is so soft that it yields considerably even under so light a pressure as $6\frac{1}{2}$ lb. per sq. in.; under such conditions the pavement is offered very little support by the subgrade and directly under the load a high stress is produced in the pavement if it is distorted thereby to a great extent, and failure is likely to result. It goes without saying, then, that the ideal condition of the subgrade is one in which the greatest possible support is offered to the pavement. One does not have to make many field investigations to assure oneself that invariably water is the primary cause of all soft subgrades, but it is not so easy a matter to ascertain to what extent water decreases the bearing value of the wide range of soils encountered. Nor is it easy to specify the best method for getting rid of the water from soils of different types. It has been observed in very many road failures that the subgrade consists of a sticky plastic clay that takes up enormous quantities of water when saturated and becomes very soft in its saturated condition. It has likewise been a matter of general observation that soils of the more porous types, such as sands and gravelly soils, are much more likely to have low bearing value under the continued action of water. Soils are graded between these extremes and no doubt their bearing value varies with the physical characteristics of the soils.

It must not be thought that heavy loads and soft subgrades are alone responsible for our road failures. We have all seen the large shrinkage cracks produced in soils of a clayey nature when they have been baked in the sun. If they will shrink to such an extent as to cause cracking, is it not reasonable that when they are again soaked with water they will show a correspondingly large expansion? And since this expansion takes place in a non-uniform manner, is it not clear that the pavement will be given non-uniform support? Moreover, it is important that we do not forget the action of frost. We are all familiar with the volume expansion produced in water as it freezes and when the subgrade is saturated and subjected to frost action, and we know that vertical expansion takes place, which in many cases produces cracking of the pavement by virtue of the inequality of this expansion in different places in the road.

All of us have observed the extreme hardness of many soils when they are perfectly dry, and no laboratory tests are needed to tell us that these same soils when they are made wetter and wetter become softer and softer and finally lose all ability to support loads. It goes without saying that one of our main subgrade problems is that of successfully getting rid of a sufficient quantity of water from the subgrade to render it of high enough bearing value that pressures produced upon it will never

[2] See The Distribution of Pressures through Earth Fills by A. T. Goldbeck. *Proceedings of the American Society for Testing Materials*, 1917.

be excessive. Our aim should be always to have the bearing value of the soil exceed the maximum pressure produced on the soil by the loads on the pavements. It happens that certain types of soil are extremely difficult to drain, using methods which are successful in other types. It has been found that tile drains that are very successful in some types of soil will do nothing more than reduce the moisture content for a few feet surrounding the drain in other types.

The Drainage Problem

One of the problems before us today is to determine the physical characteristics of soils that are susceptible of drainage treatment of a particular kind. How many engineers would think of using a soil auger in a preliminary survey of the proposed site of a new road? Yet there is no doubt that by taking borings and obtaining samples of the soil at different depths much light will be thrown on the character of support that will be offered by the subgrade and on the possibility of water being retained by the subgrade. It has been observed in several cases where failure of the road has resulted, that 2 or 3 ft. below the subgrade there was an impervious stratum which retained the water in the upper layers and kept it saturated in the spring of the year. Borings will often reveal the presence of a seepage stratum carrying continually flowing water which should be diverted from the road subgrade. These points are cited to show that the subgrade problem involves much field study as well as the mere study of the soils in the laboratory.

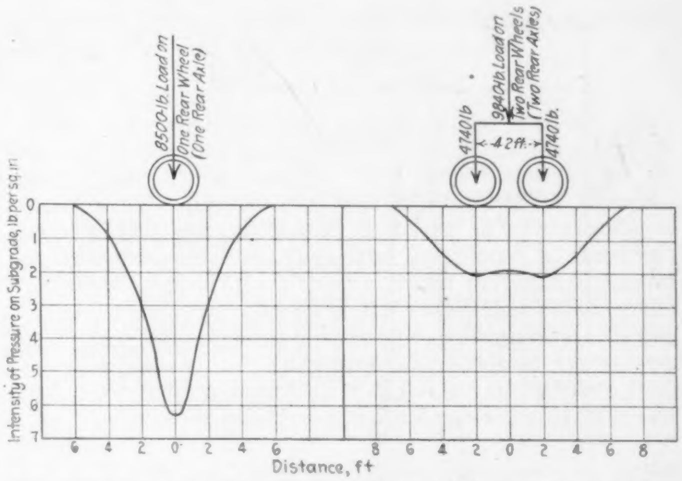


Fig. 3—Curves Showing the Intensity of Pressure Transmitted to the Subgrade through an 8-In. Concrete Slab

To reduce the water content in the subgrade to a safe minimum, drainage systems will no doubt be needed which in many cases will be very costly. Our subgrade problem is being taken up to lead us to the adequate and economical design of the road. Let us not forget that the road structure involves the subgrade as well as the wearing surface. By strengthening either we strengthen the entire structure. We can, perhaps, cheapen the road surface by strengthening the subgrade, but the strengthening of the subgrade may involve an extraordinary expense and for this reason we must not forget that we may be able in some cases to accomplish our end by

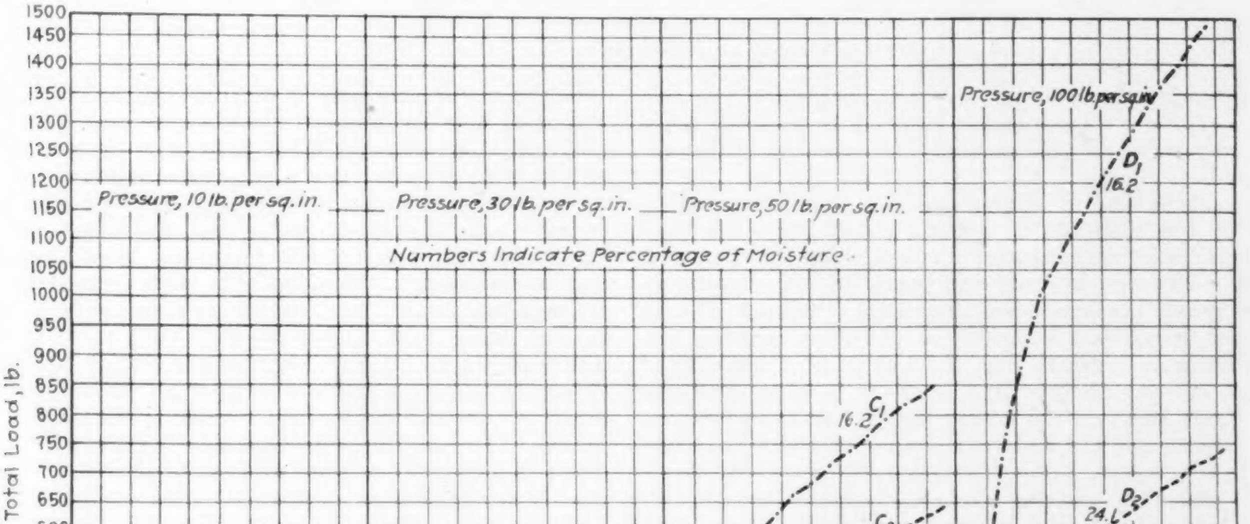


Fig. 2—Chart Showing the Bearing Power of Soils Based upon a Test with a 5-Ton Truck Having Four Rear Wheels

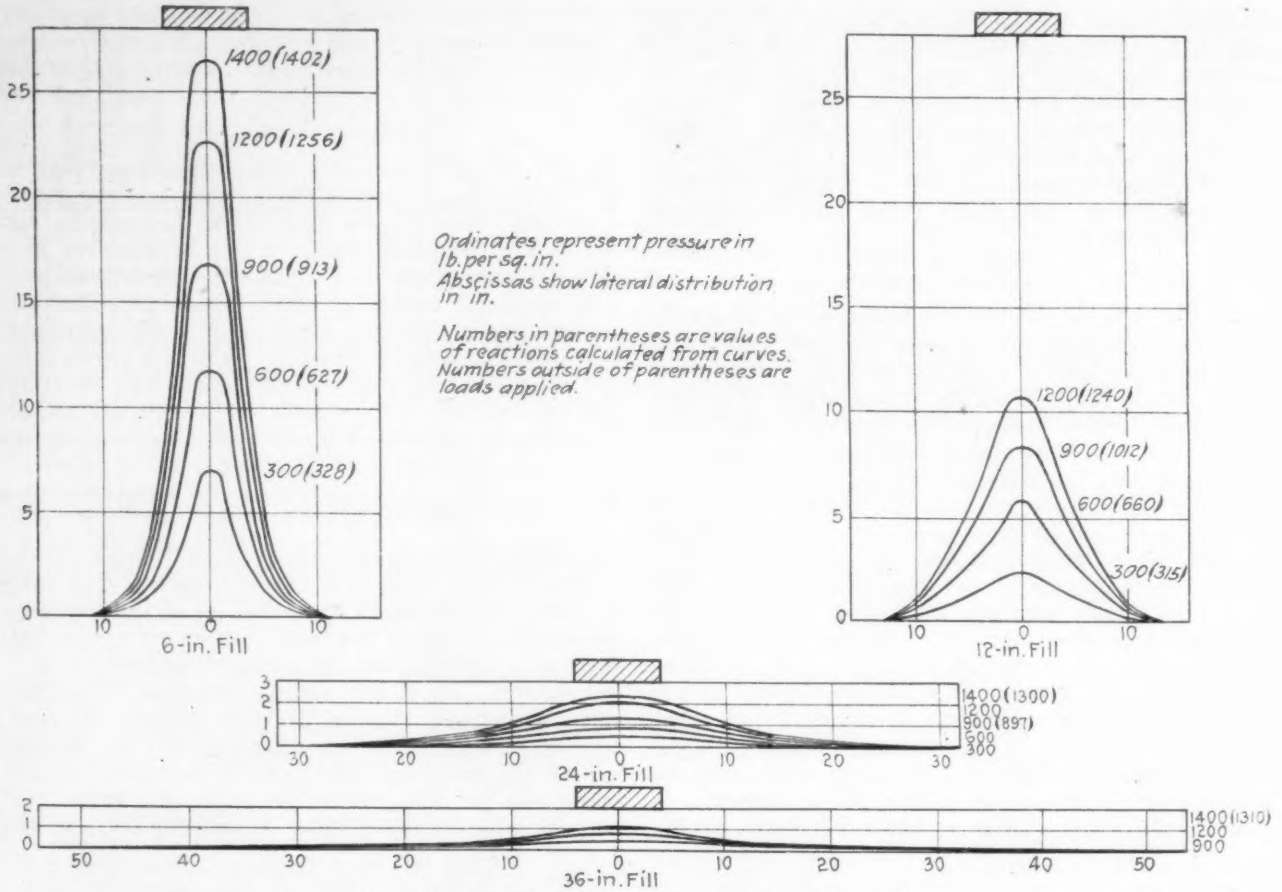


FIG. 4—PRESSURE DISTRIBUTION THROUGH DAMP SAND FILLS

strengthening the road surface to the neglect of the subgrade. These are questions of economy to work out when we know more of the methods for treating subgrade materials.

We have spoken of attempting to increase the bearing value of the subgrade by getting rid of the water, but there may be other means for accomplishing the same end. A few years ago a study was made of the manner in which heavy pressures are distributed through fills of different thickness. A typical set of curves showing this distribution is given in Fig. 4. The point to be noticed is that at very shallow depths there is high intensity of pressure and that the deeper the fill the lower becomes the intensity and the wider the area over which the pressure is distributed. This fact is significant, for it shows that if under the wearing surface of a pavement we provide a layer of material having high bearing value, then by virtue of an extra thickness of material the pressure intensity on the underlying soft subgrade may be so much reduced as to keep it below the bearing value of the soil. It is not impossible that some chemical means will be developed for changing the characteristics of soils having low bearing value, although no suitable means have thus far suggested themselves. It is likewise not impossible that by satisfactorily waterproofing the subgrade for a certain depth we can produce a waterproofed layer of material of high bearing value which will serve to distribute pressures to the soft subgrade beneath.

LABORATORY INVESTIGATIONS OF SUBGRADES

All of the preceding points are subjects for investigation and at the present time a very definite scheme of investigation of subgrades is being followed out by the Bureau of Public Roads and by other laboratories interested in these problems. Not only have investigations including field and laboratory tests been made but special drainage researches are being carried out on a large scale in the field. Some time ago a memorandum was sent to our various Federal district engineers throughout the country asking them to assign men to make special observations on roads that had failed due to soft subgrades and heavy loads. Complete data with regard to these failures were supplied, including a description of the failure, topography of the country, the condition of the drainage system, if any, photographs of the failure, the character of the traffic and in fact all information that could be obtained in the field regarding the cause of the failure. In addition, borings were taken with a soil auger in general to a depth of 5 ft., to determine whether there was any change in character of the soil at different depths, thus furnishing information as to the probable reason for the presence of large amounts of water near the surface. Large samples of the soil were obtained from those spots in the road that had failed and samples of this kind have been shipped to Washington from all over the country. Corresponding observations and samples of material have been taken from sections of some of the same roads that have not failed. We are now subjecting these samples to a number of physical tests and we hope to be able to throw light on some of the questions involved. The samples are being subjected to the following tests:

(1) Percentage of clay and of silt
(2) Mechanical analysis
(3) Slaking value
(4) Cementing value
(5) Compressive strength
(6) Bearing value

(7) Specific gravity
(8) Percentage of water retained by capillarity
(9) Moisture equivalent
(10) Colloidal content, etc.

In the present paper it will obviously be impossible to go into a description of all the methods pursued in these physical investigations, nor will such detail be necessary. These methods are described in a publication which will shortly be issued by the Bureau of Public Roads. It will be well, however, to point out the results obtained on a few samples examined, for these have already shown why roads have failed on certain types of soil and stood up well on other types. The results which are thus far most significant are the results of the bearing value test. To understand them it will be necessary to describe briefly the methods being followed in making this test. In the natural subgrade of a road soils are subjected to extremely varying conditions. At times they are saturated and again they may be perfectly dry. Sometimes they are expanded through ice action and are thoroughly saturated with moisture in that condition. They may be thoroughly compacted in either a dry or a wet condition. It has been thought necessary to attempt to simulate field conditions in the laboratory, and this is the basis of our present procedure.

The sample of soil is broken up in a mortar by a rubber-covered pestle, care being taken not to break any of the rock fragments. It is then passed through a ¼-in. screen. That portion passing this screen is then run through several rubber rolls to pulverize the soil without grinding it. The pulverized soil and the coarser materials are then combined and thoroughly mixed.

Bearing Value Test

The first consideration in making the bearing value test is to determine the range through which the moisture content should be varied. The lowest percentage of moisture is determined by the workability of the soil, that is, just enough water is added to the sample to enable it to be thoroughly mixed and placed in the small mold homogeneously. The maximum percentage should be that which corresponds to the saturation point of the soil. This is determined by the percentage of water the soil will take up by capillarity when loosely compacted. Two intermediate percentages of moisture are taken such that the interval between the four percentages is about the same.

The second consideration is the application of initial pressure which determines the compaction of the soil. Tentative initial pressures of 10, 30, 50 and 100 lb. per sq. in. are being used. The complete bearing value test on a sample of soil consists, therefore, of tests with the soil having different percentages of moisture and different applied initial pressures.

Having pulverized the sample, it is mixed with the smallest quantity of water to be used in the series of tests. The sample is kneaded with the hands, protected by rubber gloves, and then placed in a cast-iron cylinder 6 in. in diameter and 6 in. high. The plunger is then placed in the cylinder and the soil compressed in the testing machine under a definite pressure for a period of

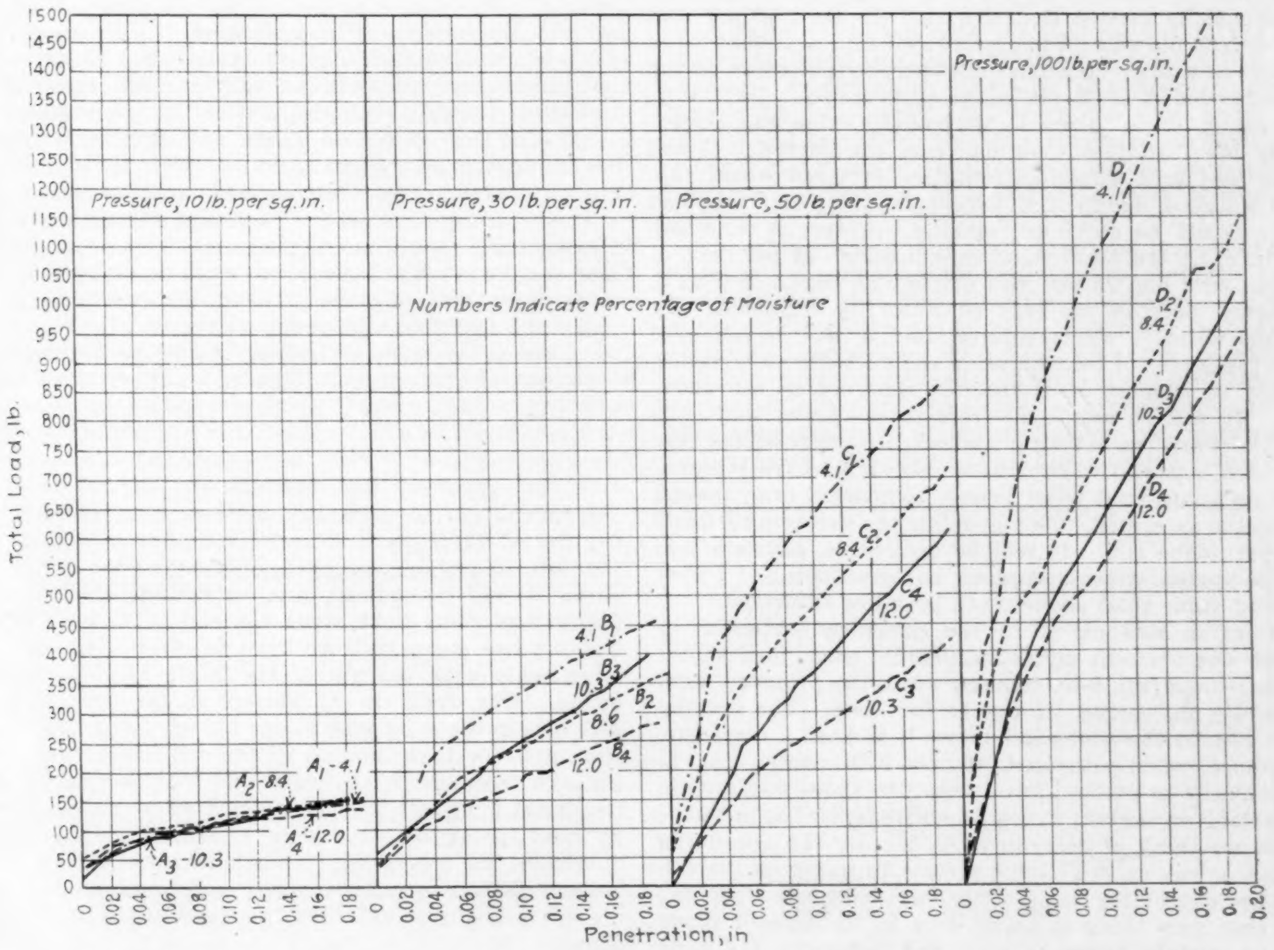


Fig. 5—Chart Showing the Bearing Power of a Soil Composed of 25 Per Cent Clay and 75 Per Cent Sand

5 min. Having subjected the sample to initial compression, the plunger is removed and a circular bearing block placed on top of the specimen; a pressure is again applied at the slowest speed of the testing machine and simultaneous readings are taken of the pressure applied and of the penetration of the plunger. The penetrations are obtained by Ames dials, reading to 0.001 in. Having completed a bearing value test with the smallest initial compression of the sample, the soil is removed from the plunger and replaced and subjected to another initial compression, and the bearing value test is repeated.

When the sample has been tested when prepared with the four initial compressions outlined above, more water is added and thoroughly mixed, and bearing value tests are again run with the soil in the wetter condition. Finally, the test is run with the soil having the highest percentage of water mixed with it that a loose sample will take up by capillarity. It will be seen that by performing the test in this way the bearing value is obtained with the soil prepared artificially, much in the same way that it is prepared by nature in that it is subjected to a range of moisture content and a range of compaction.

It is not my wish to enter into a detailed discussion of the results at the present time. I should like, however, to point out certain indications obtained with two soils having considerably different characteristics. It has been stated that observation tells us to expect trouble from road failures in the spring of the year when the subgrade is thoroughly saturated with water. In judging of the bearing value of a soil we should therefore judge it by its saturated condition. The soil shown in Fig. 2 is adobe soil and comes from a road that failed very badly. It should be noticed that this soil absorbed 42 per cent by weight of water when saturated and also that when it was saturated, no matter whether it received an initial compression of 10 lb. per sq. in. as in curves *A*, or 100 lb. per sq. in. as in curves *D*, its bearing value was exceedingly low. In fact, judging from the curves it would seem that in a saturated condition this soil would support a load of barely 2 lb. per sq. in. and under this load there would be continued sinking. A special sand-clay mixture, on the other hand, composed of 75 per cent of coarse sand and 25 per cent of clay, as shown in Fig. 5, absorbed only 16 per cent of water by weight of dry sample when it was saturated, and it will be observed that the curves of bearing value show considerably higher ability to support loads than in the case of the adobe soil. It will be seen also from these curves that soils of this character having a higher percentage of coarsely granular material when densely compacted have a higher bearing value than when loosely compacted even though the soil is saturated. This is unlike the exceedingly finely divided adobe soil. It will be noticed in addition that the sand-clay when saturated has considerably higher bearing value than adobe when both are saturated.

Attention was called to the pressures obtained by actual measurement under an 8500-lb. wheel load on the Camp Humphreys 8-in. concrete road, the pressure there being 6½ lb. per sq. in. due to this load. The bearing value test on the adobe soil shows it to have a maximum resistance, when saturated, of only 2 lb. per sq. in. Is it necessary to proceed any further to show why certain roads laid on certain types of soil have failed utterly? Would we think of designing the footing for a building in such a way as to produce greater pressure on the soil than the supporting value of the soil under that footing? Yet, that very thing is being done in the case of roads laid on certain types of soil, and naturally the soils yield with the distortion of the road surface. Before leaving the curves just described, it is interesting to note the exceedingly high bearing value to be expected even from adobe when it has a low percentage of moisture and it is tightly compacted. Such values are shown by curve *D*. This, of course, bears out our common experience that even the worst kind of clay soil will support heavy loads so long as it is dry and compact.

I do not wish to give the impression that we have proceeded far enough with our investigations to say what physical characteristics soils must possess to render them of high bearing value. I do feel, however, that we are gradually obtaining results which in the end will give us this information. It seems that our results point to the conclusion that finely grained and exceedingly plastic soils, when saturated, are likely to give a considerable amount of trouble and that the coarsely grained, more porous soils which drain well and have a high bearing value will give the least trouble. There is a gradation, however, between these types and it is our aim to couple the bearing value of these gradations with the physical characteristics and likewise with the possibility of these different soils being drained by various systems of drainage.

Drainage Investigations

No soil investigation would be complete without a study of methods for adequately draining the subgrade. It is well known that many roads have failed on fills as well as in cuts when the soil has been of a particular type; also that some soils are not susceptible to drainage such as might be used on other types. We have seen subgrade failures throughout the country where drainage was employed. We have ever before us the constant example of city pavements of comparatively light cross-section very successfully carrying extremely heavy loads, and we are forced to the conclusion that perhaps many of our so-called drainage systems are not as immediately effective as they should be at the time when most needed, in the spring of the year.

Our curiosity has been aroused as to whether some sort of drainage system that will exclude the water from the subgrade should not be designed. Our present drainage systems, it would seem, are built to carry the water away from the subgrade after it has had a chance to make the soil thoroughly wet and soft. In Fig. 6 will be observed a series of drainage experiments which has been started at Arlington Farm in an effort to determine some principles underlying the drainage of subgrades. This, in itself, is a big subject and cannot be covered in the time allotted. I have mentioned the effect expected from waterproofing the subgrade and the action of the sub-base of porous materials, both of these methods having the effect of decreasing the intensity of pressure on the soft underlying subgrade. Some of the other sections, it will be noticed, aim to exclude the water by impervious walls built along the slab. If these experiments prove successful, we hope to carry them out on a large scale with the aid of the State highway departments. Our criterion of success is the percentage of moisture in the subgrades under the various experimental sections. We take samples of the soil under these slabs through openings in the slabs and that section showing the driest subgrade may be considered as most effective. By next spring we shall know if any of the schemes is of value. In conclusion, I want to point out that the amount of research to be performed in connection with highways is almost unlimited. I have spoken of only one phase.

As some of you probably know, we have been looking

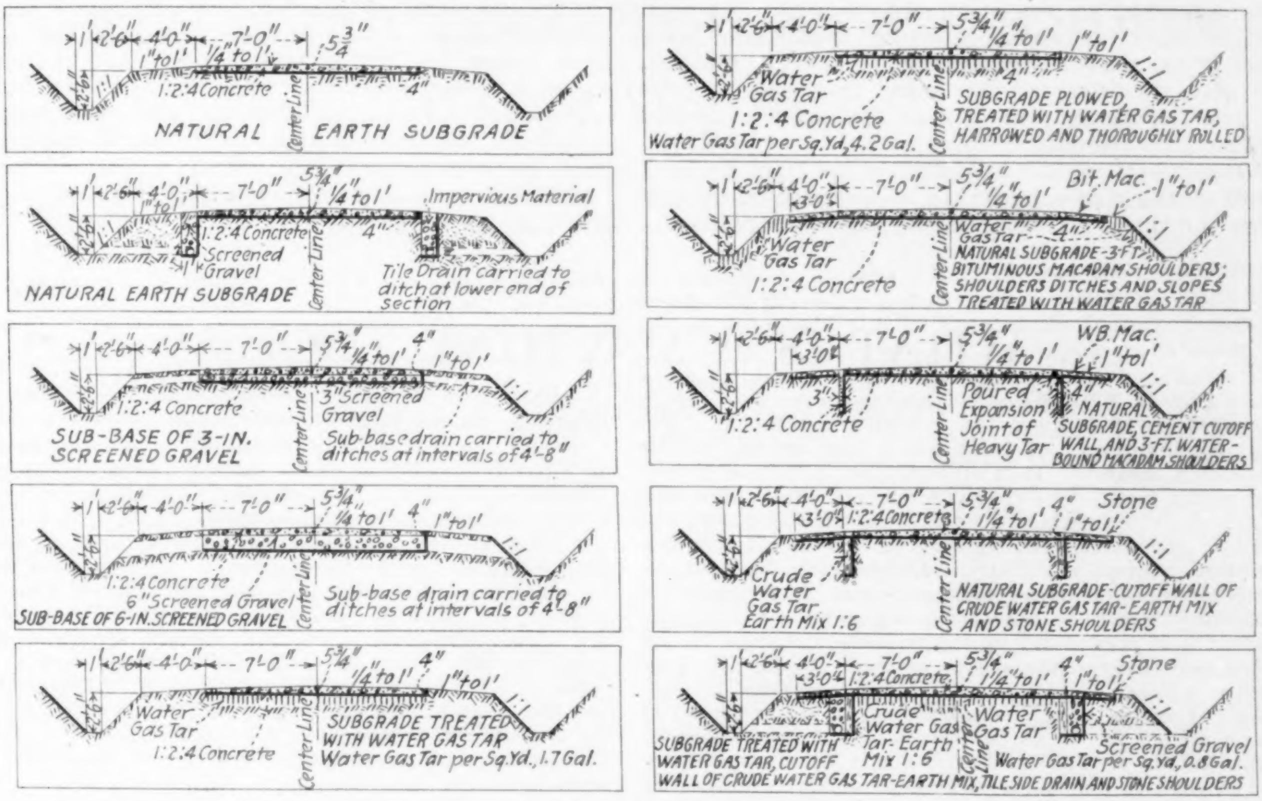


Fig. 6—Various Forms of Road Construction Which Have Been Tested at the Arlington Farm of the Bureau of Public Roads to Determine the Principles Underlying the Drainage of Subgrades

into a number of different phases of research, seeking for light on the design of roads to carry heavy trucks adequately. We feel that we have discovered a number of fundamental facts with relation to the impact effects of motor vehicles on roads and if I had the time I could no doubt show you some very interesting data bearing on the subject of weight and design of motor trucks and the different effects of tires.

We have also looked into the subject of the effect of heavy impacts on road surfaces of different types and I wish to call your attention briefly to the curves shown in Fig. 7. These represent results obtained by subjecting slabs of concrete laid on a wet subgrade to impact, an impact exactly like that delivered by the rear wheels of a 5-in. truck. The slabs were 4, 6, 8 and 10 in. in thickness, respectively. We have broken every slab on a wet subgrade except those 10 in. in thickness, and our specimens were not tested with the load applied in the most disadvantageous position but rather in the position most favorable to the slab. The 4-in. slab broke under 634 blows; the 6-in. under 1239 bows, the 8-in. under 2552 blows; and the 10-in. slab was subjected to 6000 blows without any signs of failure. The curves show directly how much difference in strength there is between a 4 and a 10-in slab.

One of our most important problems is to determine whether we cannot obtain satisfactory strength with a comparatively thin slab, provided the subgrade is maintained in satisfactory condition. I mention these experiments in connection with the subgrade experiments merely to give you some idea of some of our problems. The amount of money contemplated for expenditure and actually being expended at the present on road construction is enormous. The day is past for building roads of de-

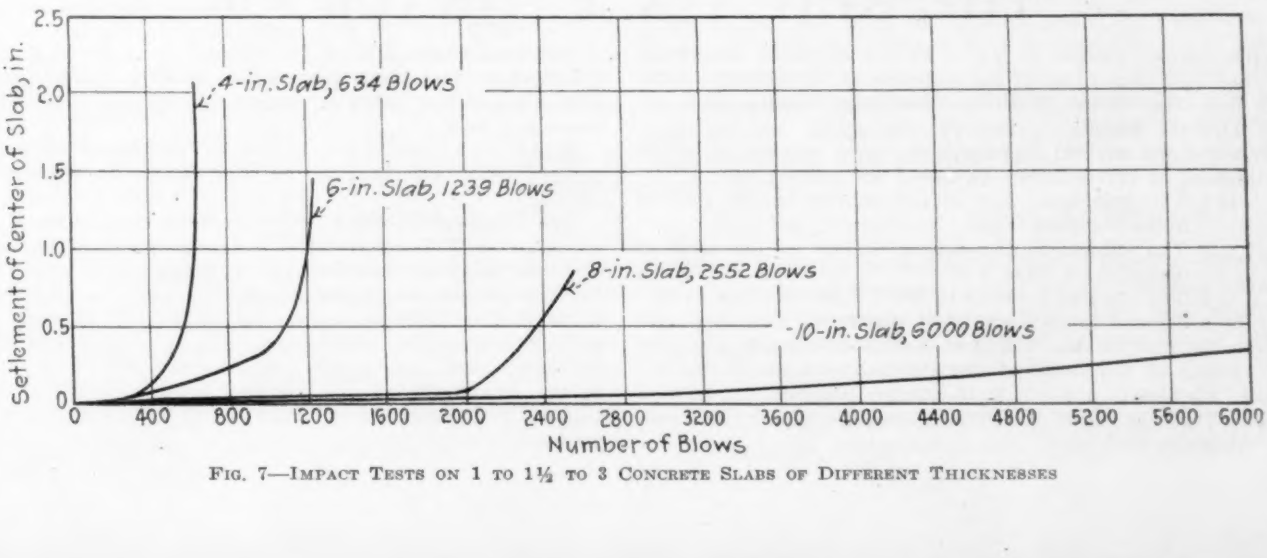


Fig. 7—Impact Tests on 1 to 1½ to 3 Concrete Slabs of Different Thicknesses

signs arrived at by rule-of-thumb. Our future designs must be based on sound, scientific, fundamental data. There is too much money involved to have it otherwise. It is our duty to expend this money in such a way that our road structures will give us the most economical service. It is the duty of those having to do with highway transportation, and this involves the truck designer as well as the road engineer, to see that the public supplying the funds get the greatest possible benefit.

Is it not manifest that road engineers and automotive engineers must meet in joint conferences to the end that road design and motor-truck design shall be mutually adapted one to the other; and to the end that these designs shall be governed with the goal very clearly in mind, that of ultimate economy in cost of haul? Ultimate economy includes motor-truck economy as well as road economy and many perplexing technical and economic problems will confront such a conference.

WHAT IS A MACHINE TOOL?

EDWARD H. KNIGHT in his mechanical dictionary, published in 1872, gives the following definitions: "*Machine:* An instrument of lower grade than an engine, its motor being separate. It is distinct from a tool, as it contains within itself its own guide for operation. *Machine Tool:* A machine in which the tool is directed by guides and automatic appliances. Among tools of this class for metals are lathes, punches, and shears. Machine tools for wood are sawing machines, planing machines, etc." It is the habit of dictionary makers to copy each other, and it is not improbable that our present-day dictionary interpretation of the word is derived from the above. It must also be said that to define a machine tool as a tool-using machine is very natural. There is some doubt, however, if the original and common use of the words is as indicated above. Cameron Knight, author of The Mechanician and Constructor, published in 1869, in the course of a very complete definition of shop terms, includes the following: "Tools include every implement small and large, simple or complex, which is used to produce or operate upon the work in the course of progress. A center-punch in a turner's pocket is a tool, and the lathe before him is a tool."

It is an easily verified fact that in the text and advertising columns of the early mechanical papers such as the *Scientific American* (1846), the *Mechanics' Magazine* (1836), and the *American Artizan* (1862), the term "machine tools" is used but seldom, and then exclusively by editorial writers. The first observed use was in 1862. "Tools" is the word that was in universal use throughout the Civil War period to indicate what we now call machine tools. Advertisements for the sale of the after-war surplus were either under this caption or under the heading "machinist's tools." This use of the word persisted into the eighties. In 1879 Frederic B. Miles formed a company with the name "Machine Tool Works." This is the first noted instance of the use of this term by a shopman. The company advertised the building of steam hammers, planing machines and lathes.

On first thought we may be inclined to define a machinist as a machine-using workman, and a machine shop as a machine-using shop, but this definition will admit weavers and textile mills to these classifications. It is evident that a machinist is a machine-*building* workman, and a machine shop is a shop that *builds* machinery. By analogous reasoning a machine tool is not a tool-using machine, but a machine-building tool; that is, a tool or machine for building machinery. This conforms to the best modern definition of the term, namely, "Machine tools are machines which, when taken as a group, will reproduce themselves." This definition has the disadvantage of being general rather than specific. As a secondary definition the following might be suggested: "A machine tool is any metal-working tool the waste from which is in the form of chips." This is specific and can be easily applied to any particular machine. It is not necessary to define a metal "chip," but it may be advisable to recall that the sparks from a grinding machine are chips. This definition excludes sheet-metal working machinery and metal-forming and forging machines, but these are probably not classed as machine tools by the majority of shopmen. In any case it is necessary to draw the line somewhere, and this seems to be the best place. This classification includes all metal-cutting machinery the action of which is a progressive cutting away of surplus stock; a gradual reduction in size until the finished dimensions are reached.

A press used for piercing sheet metal has very little in common with a lathe, a milling machine or a planing machine. They are all metal-cutting machines, but there the similarity ceases. When a press is used for forming it has nothing in common with lathes, etc., other than the fact that they are all metal-*working* machines, as are also power hammers, bulldozers, swaging machines, etc.—*Machinery.*

THE NEW S. A. E. HANDBOOK

THE revised edition of Vol. 1 of the S. A. E. HANDBOOK has been sent to all of the members of the Society. Members who have failed to receive their copy should communicate with the Society.

In using the revised Handbook the page number on which a standard is printed may be found by looking up

(1) The principal noun of the subject in the general index on page K45

(2) The subject in the proper Section of the table of contents on page v

(3) The standard direct in the proper Section

If it is desired to find out what standards have been approved for use in the different automotive industries, the key system in the table of contents may be used. For instance, standards applicable to tractor engineering have a capital T at the right of the page number under the heading "Practice."

Sections which are of no interest to a member can be removed as each Section with the general matter on pages i to xiv and the index on pages K45 to K55 makes a self-contained book.

Blank data sheets which can be purchased at any stationery store can be inserted and used as memorandum sheets.

The complete Division report or reports on each S. A. E. Standard and Recommended Practice can be found in the TRANSACTIONS of the Society by referring to the volumes for the periods corresponding to the adoption and revision dates in the footnotes appearing at the end of each standard. For example, reports referring to a standard adopted in March, 1913, and revised in August, 1915, will be found in the TRANSACTIONS for the first half of 1913 and second half of 1915 respectively commencing as a general rule on page 2.

Aerial Transportation as a Business Proposition

By Glenn L. Martin[1]

Annual Meeting Paper

AERIAL transportation includes the use of airships as well as airplanes, but in this paper I will confine my discussion principally to the commercial use of the airplane as a vehicle of transportation. In discussing the subject of aerial transportation, one is apt to lapse into analogies and comparisons with the railroad, the motor truck or the steamship, but as a matter of fact aviation has no perfect analogy, for it has no precedent. There is much that can be learned from railroad, motor-truck and steamship transportation that is helpful in aerial transportation, but the man who thinks he can apply the same rules to commercial aviation will arrive at a very sad misunderstanding.

Aerial transportation is a wholly new business, unlike any other form of transportation. It is a new industry which is really in its embryonic stage, an industry that demands high standards of personal efficiency in the men who are engaged in it. In considering the function of aerial transportation, let us, for the sake of clearness, divide it into two distinct classifications; scheduled service and special service. By the first I mean the carrying of mail, express or passengers on a definite and regularly maintained schedule, independent of or supplementary to other forms of transportation. Special service includes pleasure flights, oil-field survey, selecting industrial land-sites, planning cities, aerial photography, forest fire patrol, visiting remote points, exploration, aerial advertising, delivery of perishable products, real estate survey and industrial purposes.

The Two Classes of Service

It is to be understood that each of these two classifications of aerial transportation requires different equipment, organization and operating personnel. A scheduled service, to be of true commercial value, must be faster than any competing form of transportation and operate on schedule. Aircraft capable of at least 100 m.p.h. are therefore essential, and flights must be conducted regardless of weather conditions. Weight-carrying capacity must be sacrificed for greater speed. Since the efficiency of a service of this nature requires the very best design of aircraft, operated by a highly efficient personnel, rates naturally must be high. A scheduled service, properly organized and efficiently operated in stages of from 300 to 500 miles, should average at least 80 m.p.h. in spite of wind and weather conditions.

The most striking example of this class of service is the London-Paris Air Express. The company operating this closed its first year's service on Aug. 25, 1920, with a record of 323,355 miles flown at an average speed of 100 m.p.h. Of the 1535 flights scheduled for the year, 1448 were finished *on time*, while 83 were prevented by weather and four trips were delayed by mechanical defects but were later completed after repairs had been made. Harry Harper, technical secretary of the Civil Aerial Transport Committee in England, declares that one should lay stress on the fact that the conditions for flying are probably worse on this particular route than almost anywhere else in the densely inhabited parts of the world. Yet in spite of this weather handicap the London-Paris Air Express has an efficiency record of 94 per cent for the first year of service.

A special service does not make such high demands as a scheduled service. Speed is not so highly important and the weight-carrying capacity can therefore be increased considerably. Moreover, the maintenance of a schedule is unnecessary, and as for weather conditions it is quite possible to wait for weather. Before the day of the airplane the forest ranger was the sole means of detecting forest fires. His means of locomotion was his horse, and usually he was unable to report a fire until the conflagration had gained headway and thousands of dollars were lost before any combative measures could be taken. During 1919, it has been estimated, approximately 2,900,000 acres of National Forest lands were destroyed by fire; the damage represented a net loss of $4,500,000 and a cost to the Forest Service of $3,000,000 for fighting fires. Forest fires are now located by airplane. The picturesque figure of the forest ranger, riding furiously on horseback to give the alarm, is a thing of the past. Since the establishment of the Aerial Forest Patrol on June 1, 1920, the fire hazard has been practically eliminated. Seventeen airplanes were used for fire patrol work. They covered 235,724 miles in 2872 hr. and were instrumental in putting out 570 fires in California and Oregon. There was only one fatality on all these patrols, and only eight accidents necessitated major repairs on the planes.

Scheduled service and special service have one basic problem in common, the distance it is profitable to fly without landing for refueling. It is quite clear mathematically that a cruising radius or operation stage of over 500 miles for an airplane demands the carrying of a large amount of fuel at a great expense and sacrifice to cargo capacity. Airplanes at the present time are short-distance vehicles. Their prime advantages over airships are their speed and flexibility. Where long non-stop flights of 1000 miles and more are required, the airship, with its greater lifting capacity is, of course, decidedly more suitable. Where long-distance flights are required of airplanes, landings should be made every 300 to 500 miles for refueling. Thus it is obvious that airplanes and airships are in no way rivals at present.

Reliability of Air Transportation

Many business men believe that, from a business point of view, aerial transportation is unreliable as well as extremely expensive. Any unreliability that may exist in aerial transportation is dependent upon three factors.

(1) The operating personnel
(2) The airworthiness
(3) The weather conditions

In railroad, motor-truck and steamship transportation

[1] M.S.A.E.—President and general manager, Glenn L. Martin Co., Cleveland.

many mistakes which are errors of the personnel or its faulty organization, causing accidents or delay, get by the press with only a stick of type. Most cases are even unnoticed. In aerial transportation the story of one interrupted flight, if it results in an accident, is published in bold-face type from coast to coast. Without federal legislation operating personnel and ground organizations which are wholly incompetent to operate successfully will be hurriedly put together, even though the airplane equipment is of the best. The administrative force should be composed of men who speak and think in the language of aeronautics. With the proper organization and administration of pilots and mechanicians, there is no doubt that personal error can be reduced to a low minimum.

In considering the airworthiness of an airplane as the basic unit of aerial transportation, it is well known that until recently airplanes employed in commercial service were discarded war material, unsuitable for civil purposes. Today, however, the designing and construction of both engines and airplanes have reached such a high state of commercial adaptability that with proper organization and maintenance mechanical breakdown should seldom, if ever, occur. I do not say that the commercial airplane has reached the acme of perfection, for there is yet much to be accomplished in the improvement of both airplanes and airships. Nevertheless, the London-Paris Express Service has flown over 300,000 miles, often under conditions that have imposed severe strains on the machines as well as on the pilots, with only four interruptions caused by mechanical defects.

Weather conditions are a factor in aerial transportation over which the operative personnel had, until recently, very little direct control. In the early days of flying no aviator would think of flying in wind or storms; a perfectly calm day was necessary before he would soar into the atmosphere. In those days, of course, the airplane would not weather wind and storm, but the modern airplane will fly through wind, storm, rain or snow. There are two elements, however, which must be conquered, low clouds or fog and darkness. The difficulties involved are the possibility of losing the course of flight and the chance of misjudgment in landing. Airplanes and airships are now being fitted with directional wireless by which the pilot can ascertain his exact position at all times. Within a reasonable period of time night flying will be as common as day flying, fog and low-cloud hazards being negligible.

Terminals

With the very best design of commercial airplane and the most highly efficient organization and administration, aerial transportation can go no further than its terminals. The need for aerial terminals, municipal airdromes, is acute in the United States. The builders are producing airplanes; the engineers are working on improved types of commercial planes; transportation companies are organizing all over the country, and yet to what avail? Aerial transportation will never become universal until each and every community provides an air terminal equipped with proper facilities. Communication by wireless, telephone and telegraph should be provided, as well as rail and motor-vehicle transportation for passengers and freight, hangar accommodations, repair service and stores, gasoline, oil and sundry supplies. The progressive cities in the United States have already awakened to the fact, and I am sure the laggers would follow suit if they only realized that they are mortgaging their future by failing to grasp the tremendous advantage of being on the "main air-line." What would Chicago be, for example, if she had not been the first to recognize the possibilities of her geographical situation? A mere hamlet, or perhaps a port of minor importance. Chicago did not let opportunity knock unanswered at her door. She developed her harbor facilities and is now the biggest port on the Great Lakes, and the second largest city in the country. In the same way aerial navigation will transform many an unimportant village and bring towns out of humble obscurity into the limelight of commercial prominence.

Federal Flying Regulations

The next point I want to take up is the need of federal flying regulations. America has not yet made a beginning in this direction. Several State legislatures have passed laws providing for the regulation of air traffic within their borders, but the range of the airplane is so unlimited that the legislation of a great number of individual States would lead merely to hopeless confusion. Federal legislation is the only solution. It should not only regulate aerial traffic but provide uniform regulations for licensing pilots and aircraft, and periodic inspection of aircraft and landing fields. Other forms of transportation are inspected. Our steamship and railroad lines are made to conform with certain standards of safety before they are allowed to carry passengers; why not aircraft? Pilots entering or taking-off from any airdrome should be required to adhere rigidly to the rules and regulations. "Stunt" flying should be forbidden, even at the risk of making flying as devoid of thrills as riding on a freight train. Many lives have been sacrificed for the sake of a thrill. Provisions should be made for the adjustment of claims for injury or damages to persons or property resulting from the operation of aircraft, whether licensed or not, and these provisions should be so strict in covering the determination of responsibility for accidents that aerial transportation companies or other agencies directly concerned would not hesitate to assume the liabilities that might be incurred in operating commercial aircraft. England has recognized the necessity of federal legislation. No airplanes are allowed to fly over an English city except at a height which permits them to glide beyond the city limits in case of trouble. Heavy fines are imposed for "stunting."

Insurance

There is one phase of the aeronautical industry in which America leads the European nations, aircraft insurance. We have in the United States an organization known as the National Aircraft Underwriters Association which collects and publishes hazard statistics. These data form the basis on which insurance companies make out their policies. Today there are numerous insurance companies which issue policies to owners of aircraft. The premium is based on three determining factors, (*a*) the pilot's efficiency record, (*b*) the type of plane and its performance record and (*c*) the type of engine. The Underwriters Laboratories is planning to go into this matter more intensively. The examination of aircraft is to be conducted in the same manner as automobiles and electrical supplies are inspected. This will have a double advantage, for it will not only furnish the various insurance companies with further reliable data but give the builder some assurance that the purchaser can get insurance on his airplane. Few business men care to sink money in an enterprise that is not fully protected against accidental losses. The very fact that transportation companies in the United States can take out insurance on

their planes will probably do more to put commercial aviation "on the map" than any other single development along business lines.

Development of Commercial Transportation

Civilian aerial transportation had its birth in England in May, 1919. Germany followed closely with similar enterprises. The beginning was not very auspicious, for neither the aircraft industry nor the public was ready for commercial aviation. England's national exchequer was exhausted, her industrial system had collapsed, and yet in spite of these insurmountable obstacles commercial aviation grew and advanced. No preparations were made beyond converting a few war machines into carriers. There were no large national appropriations to promote this new method of transportation. On all sides the project contended with the skepticism of the financial wizards and the instinctive conservatism of the masses. England opened up the first continental air-route between London and Paris. Within an almost incredibly short time routes from London to Brussels, Lille and Amsterdam sprang into existence, as well as interior routes to all the principal cities in the British Isles.

While Germany was not in a position to encourage commercial aviation, German private enterprises flourished. Air-lines from Friederichshafen to Berlin were opened, using flying-boats and huge airplanes. France and Italy are now doing their best to make up for lost time. An aerial line for passengers between the French capital and Strasburg has just been instituted. This service will run three times a week. Between the Bohemian capital and Warsaw there is a daily passenger service; and Rome is now on the Continental air trade-routes.

It would not be quite true to say that there is extensive carriage of cargo and commodities over these lines, but the mere fact that Queen Alexandra was able to send her sister in Copenhagen fresh vegetables and fruits for the table the other day hints at the possibilities and practicabilities of the airplane. Shortly after the signing of the armistice, a large department store in London inaugurated an aerial delivery service to Brussels. Mail orders were filled on the day of receipt. This occurred at a time when transportation facilities were completely tied up; deliveries were being delayed weeks in transit. In accordance with the effectiveness of service the salesman who made delivery in Brussels usually came back to London with additional orders.

Why is the United States, the most progressive of nations, so backward in aerial transportation? It seems strange that we maintain such a conservative attitude toward an invention of our own, one which promises limitless possibilities and such huge financial returns?

The Air Mail Service has proved that it can not only expedite our mail deliveries, but that it is a sound and profitable business investment. "The mail must fly" has been the slogan, and the mail has flown every day except Sunday between Washington and New York City and daily to New York City, Cleveland and Chicago, defying all sorts of weather conditions for over two years.

Commercial aviation is here, but it will not develop by itself. The United States must shake herself out of her colossal inertia. She must back up the project financially. Men of brains and genius are making the development of aviation their life-work. Popular prejudice and skepticism must be overcome. The airplane is a reliable means of transportation; and not only a reliable but a safe method of travel.

In closing, I wish to cite a few statistics that were published recently regarding European air travel. Between Feb. 5 and Aug. 31, 1920, the aerial passenger and mail services of Germany have made 5378 flights, negotiating over 533,000 miles with the loss of one pilot. The public air transport over French territory, and operated by French companies abroad, flew over 700,400 miles in the past year, with but one fatality. From May, 1919, to Dec. 1, 1920, the London-Paris and London-Brussels services have made several trips daily and have had only one passenger killed. From May 17 to Sept. 30, 1920, the London-Amsterdam mail and passenger services flew 93,200 miles with no accidents of any kind. The aerial passenger, mail and express services of England have, from May, 1919, to July, 1920, a period of 15 months, flown over 1,500,000 miles or 60 times the distance around the world.

WORLD'S PRODUCTION OF PETROLEUM

The estimated world's production of petroleum in 1920 is 688,474,251 bbl. against 554,505,048 bbl. in 1919, according to figures assembled by the American Petroleum Institute. This represents a gain of 133,969,203 bbl. or 24.2 per cent.

Of the total production in 1920 the United States supplied 443,402,000 bbl. or 64.4 per cent. Mexico supplied 159,800,000 bbl. or 23.2 per cent of the world's output. By far the greater gains were made by the United States and Mexico. United States production increased from 377,719,000 bbl. in 1919 to 443,402,000 bbl. in 1920, a gain of 65,683,000 bbl. or 17.4 per cent. Mexico increased from 87,072,954 bbl. to 159,800,000 bbl., a gain of 72,727,046 bbl. or 83.5 per cent in spite of unsettled conditions.

A comparison of the statistics for 1920 and 1919 reveals the effect of the unsettled conditions resulting from the world war. Assuming that the 1920 figures are approximately correct, it will be noticed that the production in Russia declined over 4,000,000 bbl. Another noteworthy change is the shifting of the production in the Alsatian field from Germany in 1919 to France in 1920.

The estimated production for 1919 and 1920 by countries is given in the accompanying table, the figures being in barrels in all cases.

WORLD'S PETROLEUM PRODUCTION

	1920	1919
United States	443,402,000	377,719,000
Mexico	159,800,000	87,072,954
Russia[1]	30,000,000	34,284,000
Dutch East Indies	16,000,000	15,780,000
India	8,500,000	8,453,800
Roumania	7,406,318	6,517,748
Persia	6,604,734	6,289,812
Galicia	6,000,000	6,255,000
Peru	2,790,000	2,561,000
Japan and Formosa	2,213,083	2,120,500
Trinidad	1,628,637	2,780,000
Argentina	1,366,926	1,504,300
Egypt	1,089,213	1,662,184
France[2]	700,000	....
Venezuela	500,000	321,396
Canada	220,000	220,100
Germany[2]	215,340	925,000
Italy	38,000	38,254
Total	688,474,251	554,505,048

[1]No exact information available.
[2]The Alsacian field's production appears under Germany in 1919 and under France in 1920.

Developments in Transmission[1]

By Capt. S. Bramley-Moore *Illustrated with* Drawings

IN this paper it is my intention to discuss certain developments in clutch and gearbox design with a view to reducing the cost of upkeep. It has been said that more money is spent on the repair and maintenance of the average transmission system than on the engine itself. This may or may not be true, but it is certain that modern high-power engines, capable of quick acceleration, can easily overload all parts of the transmission gear. Probably, however, more trouble is caused by difficulty in gear-changing and careless clutch manipulation, the latter providing a steady source of revenue to tire manufacturers.

If the ingenuity expended on modern disc and plate clutches had been bestowed on cone clutches, the latter would have proved so cheap, simple and satisfactory that the former would have been regarded in the nature of an extravagant luxury. The development of the cone clutch has been sadly neglected, while other types have been "nursed" into public favor.

Clutches drive by friction, and surely there can be no more effective form of friction than the tapered wedge action of two conical surfaces. The disc clutch is, moreover, theoretically incorrect, due to the extra spring pressure required to drive by friction between flat plates, as compared with the wedge-shaped cone, and the uneven wear due to different rubbing speeds, owing to the fact that at every different radius of the plate there is a different velocity. When clutch springs are evenly spaced around the face of the disc it is probably impossible to guarantee that all these shall exert the same pressure, and any difference in pressure will cause uneven loading and uneven wear, the portion adjacent to the strongest spring attempting to carry more than its proper share of the drive. In spite of these inherent drawbacks the disc clutch has been so carefully developed that certain designs give very satisfactory service.

The ordinary plate clutch runs in a bath of oil, and its successful action depends upon efficient lubrication. If the oil gets too thick or congeals it will prevent the driving and driven plates from separating properly when the clutch is disengaged. This will cause the car to "creep" in traffic although the clutch pedal may be fully depressed, and it will also greatly increase the difficulty of gear-changing. When starting from rest, the teeth of the first-speed gears are likely to grate and rub together as they are brought into engagement, owing to the continued rotation of the driven portion of the clutch. This difficulty is worse in cold weather, especially if the car has been standing for a few days. In the case of a well-known American car, in which the plate clutch has to be disengaged before starting up the engine, the danger is so great that it is frequently necessary, during the winter season, to jack up the rear axle before "winding up." Thin oil, on the other hand, is likely to make the clutch too fierce.

The Cone Clutch

The ordinary leather-faced cone clutch, the pioneer type, is simple, cheap and reliable, but frequently fails to provide for a sufficiently gradual engagement when starting up from rest. This is due to the fundamental absurdity that the moment the clutch surfaces come into contact, the full pressure of the clutch spring comes into immediate operation. When the driver begins to release his clutch pedal, the clutch surfaces have not begun to make contact, and then, all too suddenly, the cones engage. At this critical point the driver very often lacks sufficient control, or the requisite delicate touch, to prevent a sudden and jerky picking up of the load.

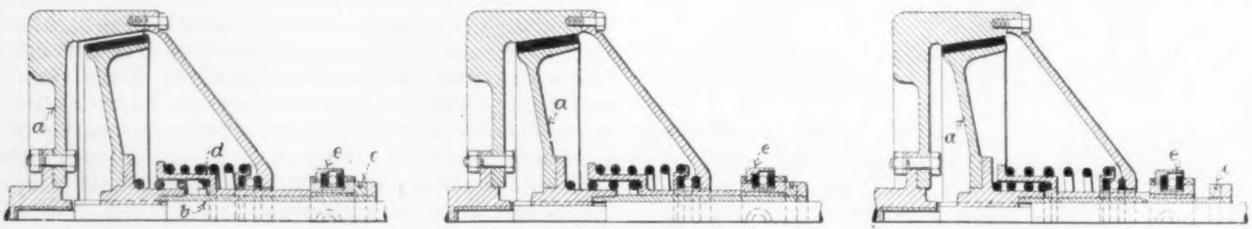


Fig. 1—Three Positions, Disengaged, Partly Engaged and Fully Engaged, of a Double-Spring Clutch

Fig. 1 shows three positions of a double-spring clutch designed to overcome this most objectionable characteristic of the ordinary type. The clutch cone *a* is operated by the sleeve *b* controlled by the collar *c*. The inner and outer clutch springs are separated by the sleeve *d* controlled by the ball thrust collar *e*, operated by a clutch pedal in the usual way. The inner spring acts directly on the clutch cone *a*, while the outer spring acts on the sleeve *d*.

The view at the left shows the collar *e* withdrawn, thereby disengaging the cone *a* through the medium of in collar *c*. In the middle view the collar *e* is shown partially released, thus allowing the cone *a* to engage with the flywheel. The inner spring is, however, as yet exerting no pressure on the cone so that the latter is only able to transmit a small torque, not sufficient to cause any jerk or jar. If, from this position, the clutch pedal be gradually released, the pressure of the inner spring will gradually increase, thus permitting the clutch to pick up its load in a smooth and uniform manner as shown at the right. Here the collar *e* is entirely released and the clutch fully engaged. Note that the inner spring is now only 2 in. long, thus exerting its full pressure, as against 2½ in. in length in the previous view. Also note the gap of ½ in. between the collars *c* and *e*, while these were previously in contact. This large travel is shown only

[1] From a paper presented at a recent meeting of the Institution of Automobile Engineers.

for illustrative purposes, and is not required in actual practice.

Fig. 2 shows an additional device fitted to this type of clutch with a view to eliminating the "human element." In this case the sleeve *f* is secured by a pin *g* to a boss forming part of the plunger *h*. When the cone *i* is withdrawn by its operating collar *j* it simultaneously moves the sleeve *f* and plunger *h*, thus allowing oil to be sucked through the passage *k* and ball valve *l* into the chamber *m*, the engine being provided with a hollow crankshaft and forced-feed lubrication. If the clutch pedal be suddenly released, the cone *i* will re-engage with the flywheel, but the sleeve *f* will be left behind owing to the dashpot *m*. This position of *f* is illustrated in the lower right corner and in this position the inner spring is extended so that it is exerting little or no pressure on the cone *i*.

As, however, the oil from the chamber *m* is gradually forced back into the hollow crankshaft, through a narrow groove that is always open, by the pressure of the outer clutch spring, so the pressure of the inner spring, acting directly on the cone *i*, will gradually increase, thus allowing the clutch to pick up its load gradually without any possibility of jerk or jar.

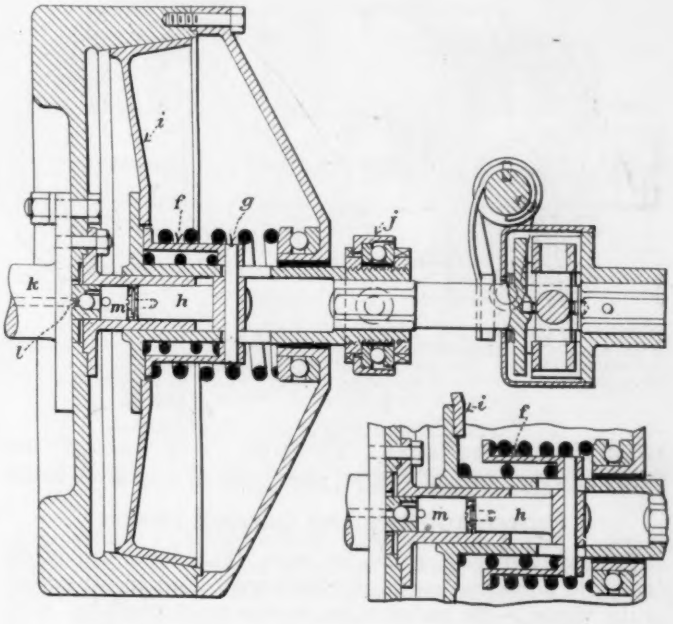


Fig. 2—Clutch with Automatic Engaging Device

It is now proposed to show how the drawbacks of the ordinary cone clutch can be overcome by a double cone and single spring, in place of the double spring and single cone already described. In the early days of motoring, when the cone clutch was almost universally adopted, many experiments were made to decide the most suitable angle of cone to give the best all-round results. The problem was how to employ a light spring without unduly increasing the diameter of the clutch. The larger the angle, the less the possibility of a fierce clutch, but the greater the difficulty in transmitting the drive, notwithstanding the use of a powerful spring. The smaller the angle, the lighter the spring, but great care was necessary in engaging the clutch; otherwise the engine would frequently be stopped, or the car jerked into motion, owing to the sudden taking up of the load.

At the left of Fig. 3 is shown a double-cone clutch combining the good points of both these two extremes in the disengaged position. This clutch comprises two driving cones, an inner and an outer, the former having a large angle, and the latter a small one. On first releasing the clutch pedal only the inner cone, with the large angle, comes into operation, as shown in the center of the illustration, and, owing to the use of a light clutch spring, this part of the clutch is able to transmit only a small portion of the power, not sufficient to cause any shock, no matter how suddenly applied. In other words, the inner cone will be compelled to slip, and this slip will allow the clutch to pick up its load gradually. Once the car is in motion the clutch pedal is fully released, thus allowing the outer cone, with the small angle, to pick up the drive, as shown at the right, and this without any risk of further slip, and with a minimum of both spring pressure and clutch diameter, which could not possibly be obtained with the orthodox pattern of single cone clutch.

In Fig. 3 the cones *n* and *o* are the driving members, both rotating at the same speed, and *p* is the driven member. In the view at the left the clutch is entirely disengaged, all three cones being out of contact with each other. In this position the clutch pedal is, of course, fully depressed. The middle view shows the position of the clutch for starting the car from rest. Only the cone *n* has engaged the driven member *p*, and this portion of the clutch is designed so that it does not possess sufficient "grip" to jerk the car, although it is able to set the vehicle in motion. This characteristic is due to the large cone angle and light clutch spring.

At the right the clutch is shown fully engaged, the driven member *p* being sandwiched between the two driving cones *n* and *o*. In this position the clutch is able to transmit the full power of the engine. There is no possibility of slip because of the powerful grip of the outer cone *o* due to the small cone angle.

When the clutch pedal is first released, the cone *n* engages with the cone *s* before the latter engages with the cone *o*. This is due to the fact that the cones *n* and *p* travel at a different rate. The driven member *p* is operated by the "slow moving" link *q*, which is pivoted half-way up the "fast moving" operating lever *r*, so that the end of *r* will move approximately twice as far as the link *q*, because the radius of the former is

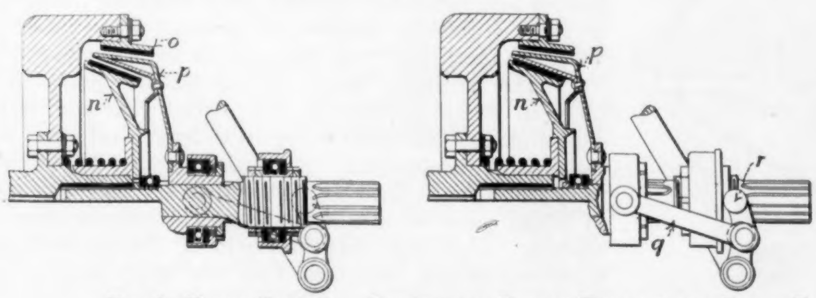


Fig. 3—Three Positions, Disengaged, Partly Engaged and Fully Engaged, of a Double-Cone Clutch

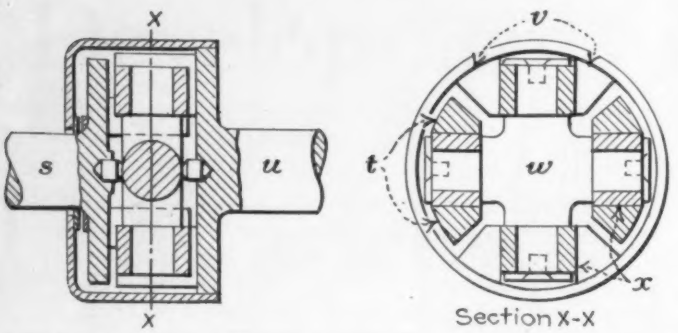


FIG. 4—A COUPLING WHICH IS A UNIVERSAL-JOINT AND IS CAPABLE OF MOVEMENT IN AN ANGULAR DIRECTION AS WELL AS CONVEYING MOTION BETWEEN TWO SHAFTS WHOSE AXES ARE PARALLEL BUT NOT IN THE SAME STRAIGHT LINE

twice that of the latter. Th terms "slow moving" and "fast moving" are, of course, used only in a relative sense.

UNIVERSAL-JOINT AND GEARBOX DESIGN

It may surprise some to hear that the "universal-joint" in common use is not universal, and in all probability there is no automobile on the road provided with a coupling which gives a universal movement. The ordinary pivoted form of coupling permits of movement in an angular direction only, and is known as a Hooke's joint. One such joint is unable to convey motion between two parallel axes not in the same straight line, in which case two joints must be used. For this reason two joints are generally fitted between the engine and gearbox of a motor vehicle when these two units are independent of each other. The Oldham coupling, on the other hand, is designed to convey motion between any two shafts of which the axes are parallel but not in the same straight line, but is not adapted to accommodate movement in an angular direction.

Fig. 4 shows a coupling which is a universal-joint in the true sense of the word, as it combines the movements of the two types of couplings already referred to. The driving shaft *s* carries jaws *t* and the driven shaft *u* carries jaws *v*. Motion is communicated from one to the other by the cross-piece *w* which is fitted with driving blocks *x*. If the blocks were rigidly fixed to the jaws *t* and *v* respectively, an ordinary type of Hooke universal joint would result, providing angular movement only. If, on the other hand, the blocks were fixed to the arms of the cross-piece *w*, so as to prevent any rotary movement, the cross-piece and blocks would be left with a sliding motion only, this movement corresponding to that of an ordinary Oldham coupling.

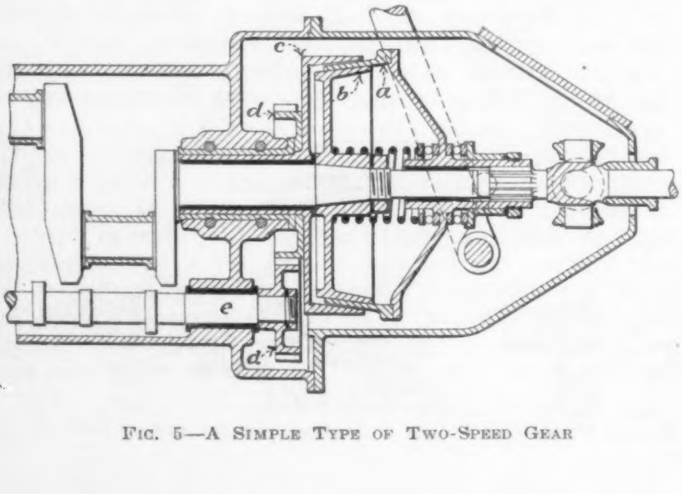


FIG. 5—A SIMPLE TYPE OF TWO-SPEED GEAR

But as the arms of the cross-piece *w* are free to pivot about the driving blocks *x*, and as the blocks are also free to slide in the jaws *t* or *v*, it will be seen that this design combines the characteristics of the Hooke and Oldham joints in one coupling. It therefore follows that one such coupling, placed between the engine and the gearbox of a motor vehicle, will meet all the requirements of both angular and parallel displacement.

There is no need to waste time in introducing the subject of gearbox design; it is an acknowledged fact that the ordinary clash type of gearbox is unmechanical and unsatisfactory. Experts pretend that there is no difficulty in gear-changing, but owner-drivers know otherwise. During 5 years' Army experience I have come in contact with thousands of drivers, being at one time responsible for the technical training of nearly 2000 men per week, and I can state definitely that the ordinary man regards the conventional gearbox as an extraordinary abomination.

Fig. 5 shows a simple type of two-speed gear designed to eliminate unnecessary gear wheels. The driven clutch cone *a* is provided with two faces, an inner and an outer. The inner face is able to engage with the high-speed cone *b*, which is keyed to the crankshaft of the engine. The outer face is able to engage with the low-speed cone *c*, which is mounted loosely on the rear end of the crankshaft, being driven from the camshaft by the low-speed gears *d*.

Under ordinary conditions the clutch spring keeps the cone *a* in engagement with *b* thereby providing the high-speed direct drive. For the low speed the clutch pedal must be depressed, thereby causing the cone *a* to engage with the low-speed cone *c*. In this position the drive will pass through the two-to-one timing-gears at the front end of the engine, which are not shown, and then along the camshaft and through the low-speed gears *d* to the low-speed cone *c*. The camshaft *e* is designed to carry this extra load, or alternatively the timing-gears can be placed alongside the gears *d*. With the arrangement shown the flywheel is located at the front end of the engine, and the reverse-speed mechanism forms part of the differential gear in the rear axle. The design of this gear is both cheap and simple, the only extra parts required being two gear wheels and an outer cone.

Figs. 6 and 7 illustrate the application of double helical gears to a four-speed gearbox. Double helical gears, unlike the ordinary straight spur type, give continuous rolling contact on the pitch line. They can also withstand a greater stress, for there is, at any instant, a stress on one portion of the tooth only, the other portions being out of engagement, while on a straight spur the stress is continuous along the whole length of the tooth. They also possess the great advantage, for automobile work, of silent running, the general design of the gear enabling a finer pitch to be employed than would be possible with a corresponding straight spur. A double helical generator has recently been made by David Brown & Sons which is adapted to produce automobile gears with the teeth cut from the solid in one continuous piece.

In the ordinary way, double helical gears are not adapted to an automobile four-speed gearbox, owing to the difficulty of restricting the length of the box to reasonable dimensions. Everybody knows that the ordinary four-speed gearbox possesses a minimum number of eight gear wheels, excluding the reverse-speed gear wheels. A unique characteristic of the present design, however, is the fact that only six gear wheels are required to provide four forward speeds, in place of the

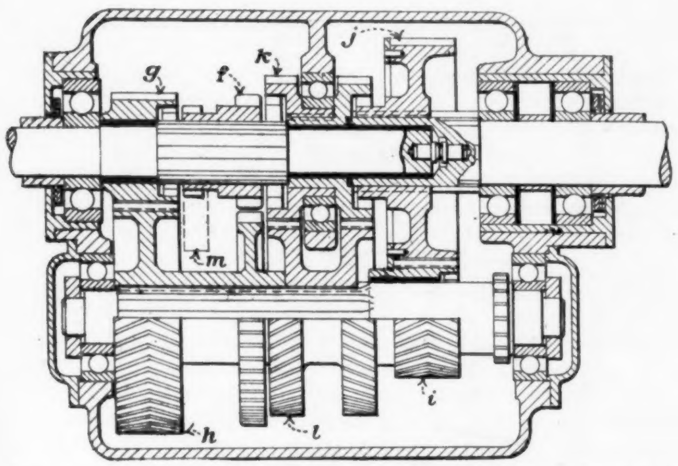


Fig. 6—Double Helical Gearbox Showing the Arrangement of the Gears for First and Second Speeds

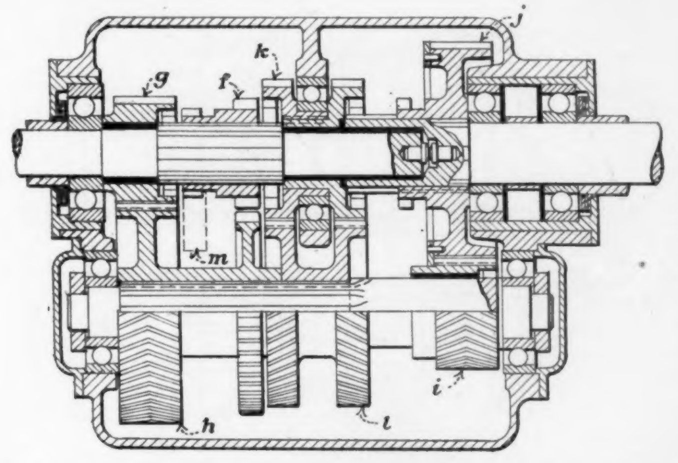


Fig. 7—Double Helical Gearbox Showing the Arrangement of the Gears for Third and Fourth Speeds

usual eight. The four speeds are obtained in the following manner:

> With the position of the gears as shown in Fig. 6, move *f* to the left for the first speed and to the right for the second speed. The drive will then pass through *g h—i j* and *k l—i j* respectively.
>
> With the position of the gears as shown in Fig. 7, move *f* to the left for the third speed and to the right for the fourth speed direct drive. The drive will then pass through *g h—k l* and *f k j* respectively.
>
> A reverse speed is obtained by moving the gear pinion *m* to the right when the gears are in the position shown in Fig. 6.

The chief characteristic of this gear, four speeds forward with only six wheels, is obtained by loosely mounting the gear wheel *k* at the junction of the driving and driven shafts, so that it can be locked to the driving shaft, or to the driven shaft, or to both together, thus enabling it to transmit power to, or receive power from the countershaft in addition to transmitting the top speed direct drive. Gear-changing is also greatly facilitated, as it is much easier to engage two sets of internal teeth, of which the shafts are rotating in the same direction, than to engage two spur gears, as in the ordinary type of box, of which the shafts are rotating in opposite directions.

The right and left-hand helicals of gear wheels *k* and *l* are shown separated by a gap, to incorporate the ball bearing supporting *k*. These are, of course, two gear wheels, not four, as both right and left-hand helicals are generated simultaneously, and the gears could just as easily be joined together, like *h* or *i*, if so required.

Fig. 8 illustrates a new type of four-speed gearbox, and the four views in Fig. 9 show the manner in which the various speeds are obtained. The characteristic feature of this box is a double-acting cone friction clutch in conjunction with six gear wheels arranged in the special manner already described so as to provide for a range of four speeds. The double clutch provides for a change of speed from first to second or from third to fourth or vice versa without touching the gearbox change-speed lever, thereby greatly facilitating the operation of changing speed.

The driving member of the clutch, *n*, is provided with two faces, an inner and an outer, so that it is able to engage with either of the driven cones *o* or *p*. The cone *o* is keyed to a sleeve carrying the gear pinion *q*, and the cone *p* is mounted on a castellated shaft *r* to which the gear pinion *s* is also keyed. The pinions *q* and *s* engage with two gear wheels *t* and *u* mounted on the countershaft; the latter also carries a gear pinion *v* engaging with a gear wheel *w* mounted on the castellated driven sleeve *x*.

For the first and second speeds the gear wheel *w* is engaged with the gear pinion *v*. For the third and fourth speeds the wheel *w* is moved over to the left, so that it engages, through dog clutches, with the gear pinion *s*, which is thus locked to the driven sleeve *x*. Thus the change-speed lever controlling the gear *w* has only to be moved when changing from second to third speed or vice versa.

In shifting the gears to get the first speed at the upper left corner of Fig. 9 the clutch pedal is pushed forward so that the cone *n* drives the cone *o*. Then *q* drives *t* and *v* drives *w*. To obtain the second speed in the lower left corner the clutch is released so that the clutch spring forces the cones *n* and *p* into driving engagement. Then *s* drives *u* and *v* drives *w*. In the third speed at the upper right corner the gear *w* has been moved over so as to lock the gear *s* to the driven sleeve *x* (see Fig. 8), and the clutch pedal is pushed forward so that the cone *n* drives the cone *o*. Then *q* drives *t* and *u* drives *s*. To obtain the fourth speed in the lower right corner the clutch pedal is released so that the clutch spring forces the cones *n* and *p* into driving engagement. Then *s* drives *w*, thus giving a direct through drive.

For a reverse speed the gear *w* is left in a neutral position and the pinions *y* and *z* (see Fig. 8) are moved

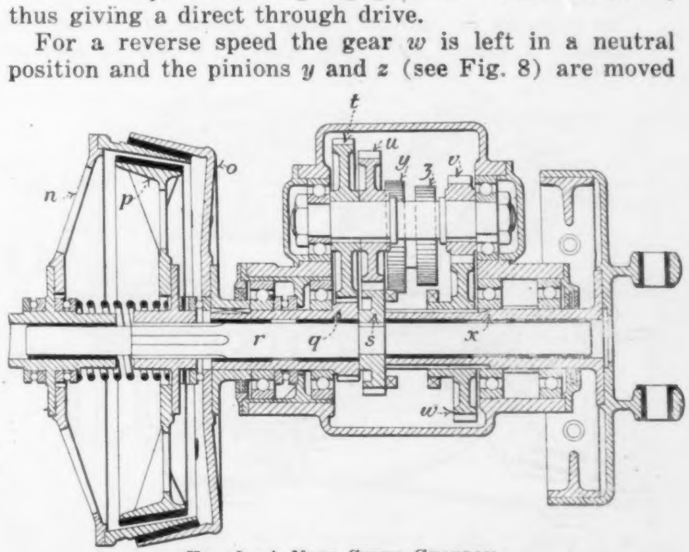


Fig. 8—A Four-Speed Gearbox

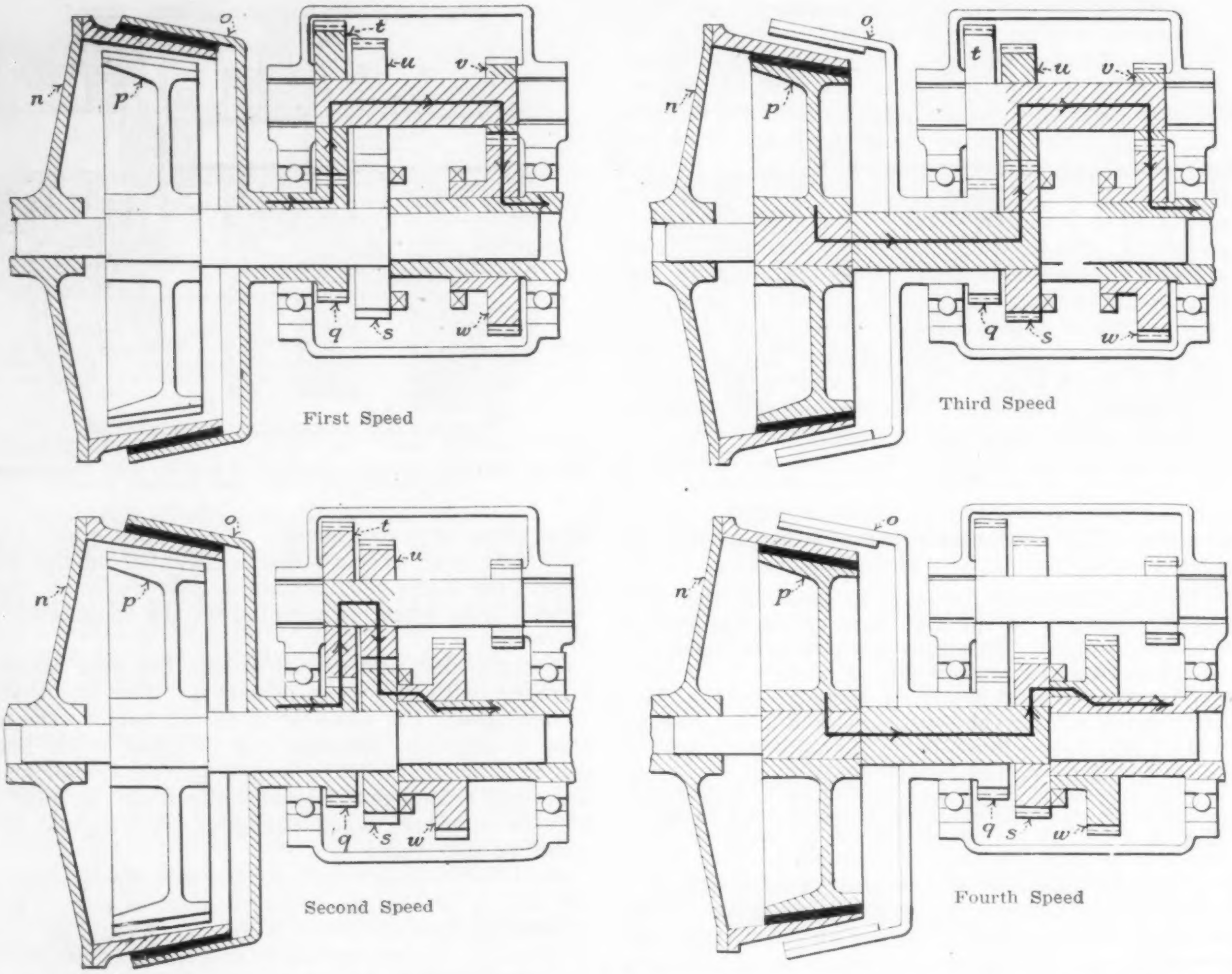


FIG. 9—DIAGRAM OF A FOUR-SPEED GEARBOX SHOWING THE ARRANGEMENT OF THE GEARS TO SECURE VARIOUS SPEEDS

into mesh with the two gear wheels w and v respectively. In this position if the clutch pedal be pushed forward it will give a low reverse speed for traffic work, and if released will give a higher reverse speed for use on a country road, having, for example, overshot the desired turn by perhaps 100 yd. The clutch is, of course, in neutral when the clutch pedal is in any intermediate position.

The gate, as far as the forward speeds are concerned, is merely a single slot, one end of which is marked

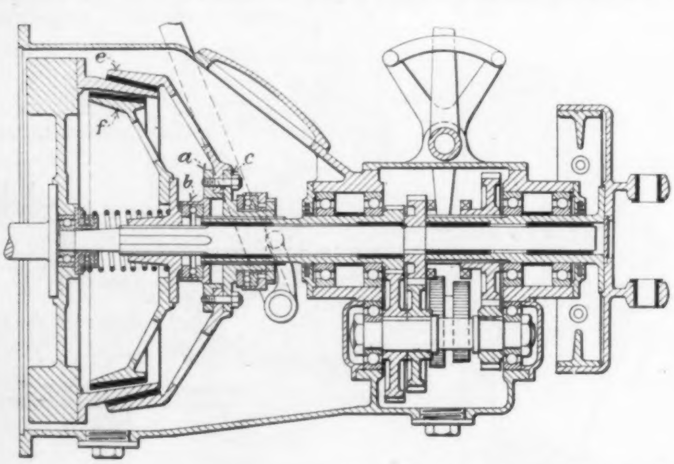


FIG. 10—A UNIT CONSTRUCTION FOUR-SPEED GEARBOX WHICH IS CAPABLE OF BEING BOLTED TO THE REAR END OF THE CRANKCASE

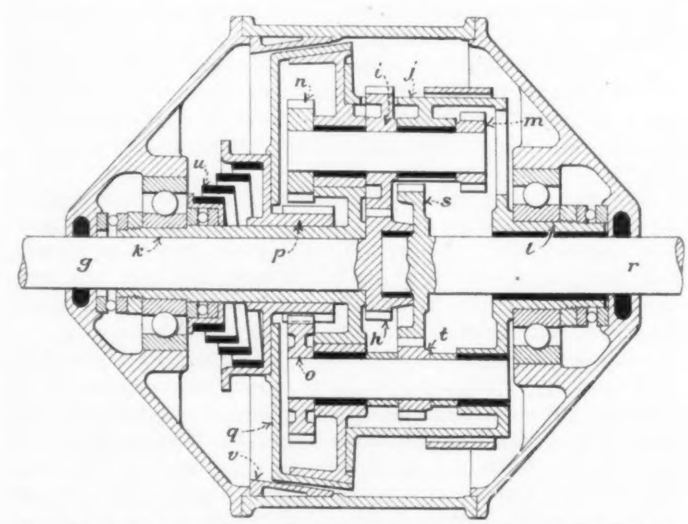


FIG. 11—EPICYCLIC GEARBOX PROVIDING FOUR FORWARD SPEEDS AND A REVERSE SPEED

"slow" and the other end "fast." The "slow" position provides for first and second speeds and the "fast" position for third and fourth speeds. A ratchet device, capable of instant release, automatically holds the clutch pedal forward when on first and third speeds. For a momentary change, however, as when starting from rest, or when dropping into third speed for a few sec-

onds for traffic congestion, this ratchet would not be brought into operation.

It will be observed that the clutch angles of the inner and outer cones are different. As the inner cone is never used for starting the car from rest, a small angle can be used, although naturally the angle must not be decreased below that point at which the clutch might "stick," rendering it hard to disengage. A small angle enables a weak clutch-spring to be employed, and this reduces the pressure required to hold the clutch pedal in a neutral position. The outer cone is used for starting the vehicle from rest, and a corresponding angle may be chosen, thus facilitating easy clutch engagement. The outer cone may be engaged without transmitting any drive, and then, as the pressure on the clutch pedal is gradually increased, the clutch will gradually pick up its load without jerk or jar. Clutch adjustment is rarely necessary, owing to the fact that two clutch faces take the drive, one on the first and third speeds and the other on the second and fourth speeds, thus distributing the wear and prolonging the life of the clutch lining. In Fig. 8 suitable packing washers are provided, however, which regulate the distance between the two clutch faces *o* and *p* should adjustment ever become necessary.

Fig. 10 shows a somewhat different design adapted to bolt up to the rear end of the engine crankcase. In this case the gate and change-speed lever are carried by the lid of the gearbox, and self-locking clutch adjustment is provided as follows: The discs *a* and *b* are screwed together, and can have no relative movement when the bolts *c* are in position owing to the castellations of the sleeve *d*, the disc *b* being castellated to correspond. When, however, the bolts *c* are withdrawn, the cone *e* can be rotated about *b*, thus drawing the driving surfaces of *e* and *f* more closely together to compensate for wear. It may be remarked that this gearbox is 35 per cent shorter than the ordinary type, and requires only two selector rods in place of the usual three.

Epicyclic Gears

The advantages of epicyclic gears are too well known to need emphasizing in this paper. In the past, however, they have suffered, when designed to transmit three or four speeds, from two serious defects, weakness of construction and a general complication of parts. It is hoped that Figs. 11, 13 and 14 will open up a new point of view, and the more thoroughly these designs are discussed, the more helpful it will be for the future development of this type of gear.

In Fig. 11 the driving shaft *g* carries the sun wheel *h* meshing with the planetary gear *i* mounted in bearings carried by the cage *j*. This cage is supported by the sleeves *k* and *l*, the parts *j* and *k* being rigidly bolted together. Thus the cage *j* is of rigid construction, being

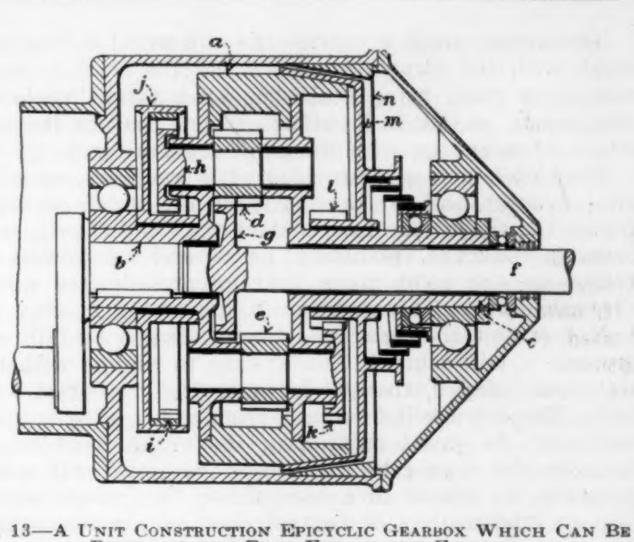


Fig. 13—A Unit Construction Epicyclic Gearbox Which Can Be Bolted to the Rear End of the Engine

carried by two large ball bearings, one at each end of the gearbox casing as shown. The spindle of the planetary gear *i* carries two additional planetary gears, *m* and *n*, the latter meshing with the planetary gear *o* which

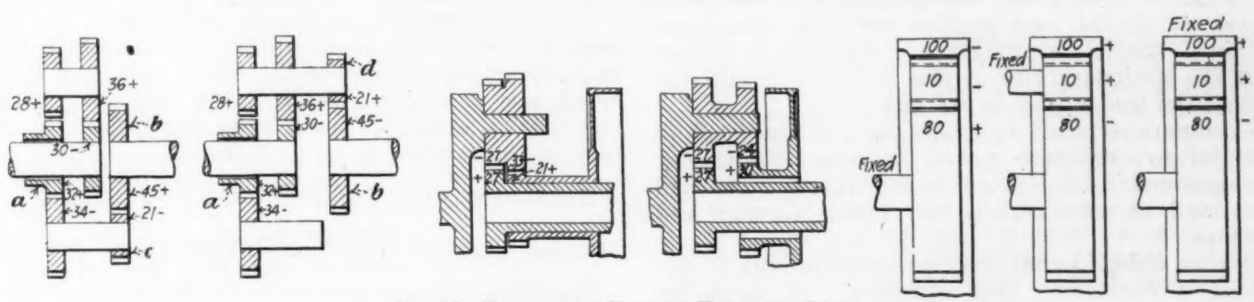


Fig. 12—Diagram of Various Epicyclic Gears

engages with the sun-wheel *p* controlled by the clutch cone *q*. For the sake of simplicity, the drawing shows the planetary gears *n* and *o* separated from each other, although it must be understood that the spindles are actually arranged so that these two gears are in continual engagement with each other.

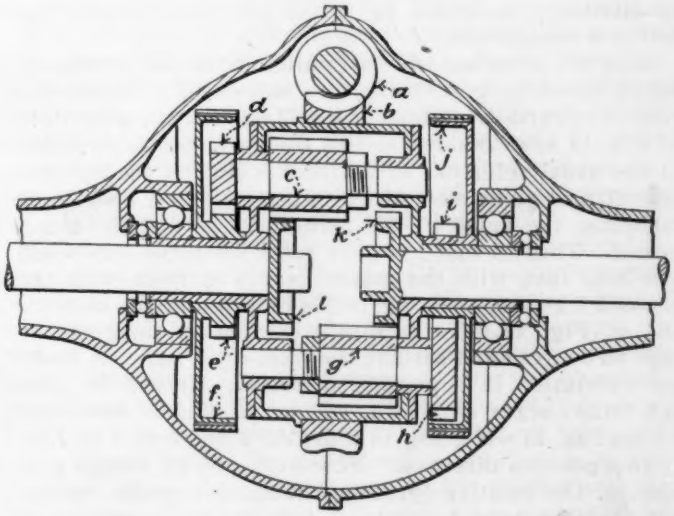


Fig. 14—An Epicyclic Gear Designed to Form Part of a Rear-Axle Spur-Type Differential

The driven shaft *r* carries the sun-wheel *s* shown in mesh with the planetary gear *t*, but the shaft *r* is arranged to slide, being controlled by external operating mechanism, so that in its other extreme position the sun-wheel *s* can engage with the planetary gear *m*.

The clutch cone *q* is provided with two faces, an inner and an outer, and for the top speed the clutch spring *u* forces the inner face into contact with the cage *j*, thus causing the cage, planetary gears and sun-wheels to rotate as one solid mass, thereby providing a direct through drive. This position is illustrated in Fig. 11.

If, however, the clutch pedal controlling *q* be fully depressed, it will cause the outer cone to engage with the stationary ring *v*, thereby bringing the sun-wheel *p* to rest. The drive will then pass from *g* to *i*, *n* to *o* and *t* to *s*. If the pedal controlling the brake band which encircles the cage *j* be depressed, the action will automatically, by means of a cam, throw the clutch cone *q* into an intermediate or neutral position, simultaneously bringing the cage *j* to rest. The drive will still pass through the same gear wheels as before, only in this case the cage *j* will be stationary and the sun-wheel *v* idly rotating, thus bringing a different gear ratio into action.

The shaft *r* carrying the sun-wheel *s* should now be moved so as to bring *s* into engagement with the planetary gear *m*. In this new position two more speeds can be obtained, one by bringing the clutch cone *q* to rest against the stationary ring *v*, and the other by the operation of the brake band on the cage *j*.

The ordinary type of epicyclic gear, if designed to provide for five different speeds, becomes both clumsy and complicated. The design in Fig. 11 is rigid and compact, and, as shown, gives four speeds forward and one reverse.

It may be objected that the sliding movement of the sun-wheel *s* eliminates that simplicity of operation which is one of the great features of the epicylic gear. This objection is not, however, very serious owing to the fact that the fourth, third and second speeds are all obtained with *s* in mesh with *t* as shown in Fig. 11. It is quite easy, except on hills, to start up on second speed, so that *s* need never be moved except in case of an emergency or for reversing. It is believed that this design is more or less unique, and it is put forward, not so much as a solution of the problem, but rather as an incentive to stimulate designers to investigate new possibilities hitherto unexplored.

It is not everyone who is familiar with the process by which epicyclic gear ratios are calculated. Those who rely on cut-and-dried formulas will not find the gear ratio of Fig. 11 easy to solve, as this design is not to be found in the usual reference or textbook. But by the application of first principles, which is better than a bookful of formulas, the value of the ratios can be quickly ascertained. Thus to find the gear ratio when the sun-wheel *a* is held fast, with the driven gear *b* in mesh with the planetary gear *c*, as shown in the diagram at the extreme left of Fig. 12. To facilitate calculation imagine the cage to be fixed and assume the fixed member, *a*, to make one revolution in a positive direction. Insert the plus and minus signs as shown, whence it will be seen that *h* (see Fig. 11) is going in a negative and *b* or *s* in Fig. 11 in a positive direction. Now work out, by simple proportion, the relative speeds of these two gears, taking care, in each case, to subtract 1 from the answer so as to eliminate the fictitious plus 1 revolution which the fixed member *a* was assumed to make. The figures in the diagram indicate the number of teeth in the gears. Then the speed of the driver equals

$$-\left(\frac{32}{34}\times\frac{34}{28}\times\frac{36}{30}\right)-1=-2.37 \text{ revolutions}$$

The speed of the driven gear equals

$$+\left(\frac{32}{34}\times\frac{21}{45}\right)-1=-2.56 \text{ revolutions}$$

The gear ratio is the quotient of the speed of the driver divided by the speed of the driven gear or $-2.37 \div -0.56 = +4.23$. The final answer, being positive, indicates that the gear ratio is 4.23 to 1 in a forward direction.

To find the gear ratio when the sun-wheel *a* is held fast, with the driven gear *b* in mesh with the planetary gear *d*, as shown in the second diagram of Fig. 12. Insert plus and minus signs on the assumption that the fixed member *a* makes plus one revolution with the cage stationary. Then the speed of the driver equals

$$-\left(\frac{32}{34}\times\frac{34}{28}\times\frac{36}{30}\right)-1=-2.37 \text{ revolutions}$$

The speed of the driven gear equals

$$-\left(\frac{32}{34}\times\frac{34}{28}\times\frac{21}{45}\right)-1=-1.53 \text{ revolutions}$$

The gear ratio determined as in the previous case is $-2.37 \div -1.53 = +1.55$.

Two more speeds can be obtained with a stationary cage, one with *b* in mesh with *d*, and the other with *b* in mesh with *a*. Obviously the former will be a forward speed, and the latter, owing to the introduction of an intermediate gear, is bound to be in the reverse direction, the gear ratios being as follows:

$$\text{Forward speed} = +\left(\frac{36}{30}\times\frac{45}{21}\right) = +2.57 \text{ (} d \text{ driving } b\text{)}$$

$$\text{Reverse speed} = -\left(\frac{36}{30}\times\frac{34}{28}\times\frac{45}{21}\right) = -3.12 \text{ (} a \text{ driving } b\text{)}.$$

The three forward speeds which can be obtained with *b* in constant mesh with *d* are, therefore, 2.57, 1.55 and 1.0 or direct, equivalent to 15.5, 26.0 and 40 m.p.h. For the reverse speed and the emergency forward speed, *b* has to be moved into mesh with *a*.

To calculate any epicyclic gear ratio, without resorting to formulas, which are sometimes unobtainable, the following system, common to all types, can be employed:

(1) Assume the planetary arm to remain stationary
(2) Assume the fixed member to make one revolution
(3) Ascertain directions by inserting plus and minus signs
(4) Calculate, from (2), the revolutions of the driver and subtract one
(5) Calculate, from (2), the revolutions of the driven gear and subtract one
(6) Divide (4) by (5). The answer gives the gear ratio

A simple but interesting example is that of the Ford epicyclic gear. With a dismantled gearbox on the workshop table, I have asked competent mechanics to explain the working of the gear. Pitying my ignorance, they have cheerfully undertaken the task, but after 10 min. of unnecessary preamble they often scratch their heads, being quite unable to explain why the car should go backward on the reverse speed. Neglecting formulas, and working from first principles, the proposition is, however, extremely simple. The third diagram in Fig. 12 shows the train of gears used to obtain the low forward speed, and the next one shows the train used for the reverse speed.

In both cases insert plus and minus signs, as shown,

imagine the planetary arm fixed, in this case it is really the driver, and assume the fixed member to make one revolution in a positive direction.

Then, in the third diagram the revolutions of the driver equal — 1 and the revolutions of the driven gear equal

$$+\left(\frac{21}{33}\times\frac{27}{27}\right)-1=-0.36.$$

The gear ratio is $-1\div-0.36=+2.76$. In the next diagram the revolutions of the driver equal — 1 and the revolutions of the driven gear equal

$$+\left(\frac{30}{24}\times\frac{27}{27}\right)-1=+0.25.$$

The gear ratio is $-1\div+0.25=-4.0$, the backward direction being indicated by the minus sign.

From an examination of the above it will be obvious that if both sun gear wheels have an equal number of teeth, the gear ratio will be zero; in other words, if the brake-drum were held fast the driven shaft would remain stationary because the revolutions of the driver equal — 1 and the revolutions of the driven gear equal

$$+\left(\frac{27}{27}\times\frac{27}{27}\right)-1=0$$

It is equally important to note that, in the above case, when the fixed sun is smaller than the driven sun, the resulting speed will be forward, but if the fixed sun be the greater, the driven shaft will rotate backward.

The ratios of an epicyclic train with an internal gear can also be instantly calculated. Three gear wheels can provide six different combinations, and three different diagrams are necessary in order that the plus and minus signs may be inserted. Proceeding exactly as before, the gear ratios of the last three diagrams of Fig. 12 can be quickly ascertained.

In the first of the combinations the sun wheel is fixed while the planetary aim drives the internal gear. The revolutions of the driver equal — 1; the revolutions of the driven gear equal — $(80\div100)-1$ or -1.8 and the gear ratio is $+0.56$. In the next combination which also refers to the same diagram the sun wheel is fixed as before but the planetary arm is driven by the internal gear. The revolutions of the driver equal — $(80\div100)$ -1 or -1.8; the revolutions of the driven gear equal -1 and the gear ratio is $+1.8$.

In the first combination for the next diagram the planetary arm is fixed and the sun wheel drives the internal gear. As the planetary arm is fixed epicyclic motion is eliminated and the gear ratio is therefore — $(100\div80)$ or -1.25. In the next combination the planetary arm is fixed and the sun wheel is driven by the internal gear. Epicyclic motion is again eliminated and the gear ratio is — $(80\div100)$ or -0.8.

In the next combination which refers to the diagram at the extreme right, the internal gear is fixed and the planetary arm drives the sun wheel. The revolutions of the driver equal — 1; the revolutions of the driven gear equal — $(100\div80)$ $1=-2.25$ and the gear ratio is $+0.45$. In the sixth and last combination the internal gear is again fixed while the sun wheel drives the planetary arm. The revolutions of the driver equal — $(100\div80)-1$ or -2.25; the revolutions of the driven gear equal -1 and the gear ratio is $+2.25$.

Fig. 13 illustrates an epicyclic gear adapted to bolt up to the rear end of the engine casing. The flywheel *a* is bolted between the two sleeves *b* and *c*, carried by two large ball bearings as shown. This type of gear is quite different from that shown in Fig. 11, inasmuch as in this case the planetary gears are carried by a continuously rotating cage, *b*, which is keyed to the crankshaft of the engine.

To simplify the drawing, the two planetary gears *d* and *e* are shown separated from each other, although their spindles are actually mounted so as to enable the two gears to engage with each other over approximately half their face width, similar to the arrangement of an ordinary spur-type differential gear. The driven shaft *f* is controlled by operating mechanism so that the sun-wheel *g* can be brought into mesh with the planetary gear *d* alone, or, in a midway position, with planetary gears *d* and *e* simultaneously, or with the planetary gear *e* alone.

The spindle of the planetary gear *d* carries another planetary gear *h* meshing with the internal gear wheel *i* controlled by the brake-drum *j*. The spindle of *e* carries another planetary gear *k* in constant mesh with the sun-wheel *e* which can be brought to rest by the clutch cone *m*, which is capable of engaging with the fixed ring *n*.

Only seven gear wheels are shown, although additional gears should be embodied for the sake of balance and even load distribution and with these few parts the gear is capable of providing four speeds forward and one reverse. Having already explained Fig. 11 in detail, the action of the present design may be briefly summarized as follows:

> For the direct drive release the clutch pedal so as to allow the clutch cone *m* to engage with the flywheel *a*, thereby causing the planetary gears and sun-wheels to rotate as one solid mass. Still leaving the sun-wheel *g* in mesh with the planetary gear *d*, two additional speeds can be obtained, one by engaging the clutch cone *m* against the stationary ring *n*, and another by holding the brake-drum *j* with the clutch cone *m* in neutral.
>
> To obtain the remaining two speeds, slide the sun-wheel *g* into mesh with the planetary gear *e*, and hold the clutch cone *m* for the lowest forward speed and the brake-drum *j* for the reverse speed.

While correctly proportioned gear ratios are easily obtainable with the design shown in Fig. 11, the ratios in Fig. 13 are more difficult to arrange, it being impossible to obtain a direct drive on the top speed. It may be remarked, however, that a direct drive on the third speed with an indirect top speed has been successfully employed by certain automobile builders.

Rear Axle Design

Fig. 14 shows an epicyclic gear designed to form part of a rear-axle spur-type differential. Apart from the ordinary differential gears, the extra parts required are two sunwheels and two planetary-gears, these latter may be added to as desired, and with these few parts the gear is capable of providing four speeds forward and one reverse. The top forward speed, geared up, is, however, too high a ratio for ordinary road use.

The worm *a* drives the wormwheel *b* which is fixed to the differential casing. The spindle of the differential planetary gear *c* is extended to carry the planetary gear *d* meshing with the sun-wheel *e* which can be brought to rest by the brake-drum *f*. In the same way the spindle of the differential planetary gear *g* carries the planetary gear *h* meshing with *i* controlled by the brake-drum *j*. The rear-axle cross-shafts are of the floating type, and are arranged so that the sun-wheels *k* and *l* can be moved sideways by a change-speed lever and the usual selector mechanism. The brake drums *f* and *j* are controlled by two pedals.

The position of the gears in Fig. 14 shows the direct

drive in operation, the differential gear functioning as such in the usual manner, the drums f and j revolving at the same speed as the differential cage. When k is moved to the extreme left, so as to engage with the planetary gear c, two more speeds are available by locking the brake-drums f and j respectively. When l is moved to the extreme right, so as to engage with the planetary gear g, two more speeds are available by once again locking f and j respectively, thus providing a total range of four speeds forward and one reverse. On the indirect speeds the gears c, g, k and l cease to function as a differential.

Many motor trucks have been tested under the most strenuous conditions after their differential gears have been removed. It has been stated by W. O. Thomas[2] that

> These gave surprisingly good results, and instead of decreasing the tire mileage, as would be expected, the mileage appeared to increase. This could only be attributed to the decreased slip of the wheels on the granite block pavements and in the mud and holes near the front. These trucks would pull over almost impossible places, and were the best evidence of the need of limited action.

One of the earliest examples of a live axle designed to eliminate the bugbear of unsprung weight was the De Dion Bouton motor car, and the same design is still adhered to in the 1921 De Dion Bouton commercial vehicle. The design unfortunately necessitates the use of four universal-joints, two on each side of the rear axle casing, without taking the propeller shaft into account. Fig. 15 illustrates a method of eliminating unsprung weight in which only one universal-joint is required in place of the usual four.

In the plan view at the right of Fig. 15 the bevel casing m is suspended by a pivoted link n from the rear cross-member o of the chassis. The axle sleeve p terminates in a spherical ball q which allows the sleeve to have a universal movement with respect to the case m. The other half of the bevel casing, r, carries the axle sleeve s, the outer extremities of the two sleeves s and p carrying the rear road wheels in the usual manner.

It will be seen that this design not only insulates the transmission gear from all road shocks, and reduces the unsprung weight of the vehicle, but in addition provides each road wheel with independent motion when rising or falling over obstructions through the universal-joint t which is concentric with the ball joint q and which allows the shafting to adapt itself to the angularity of the axle sleeves caused by the irregular movement of the road wheels.

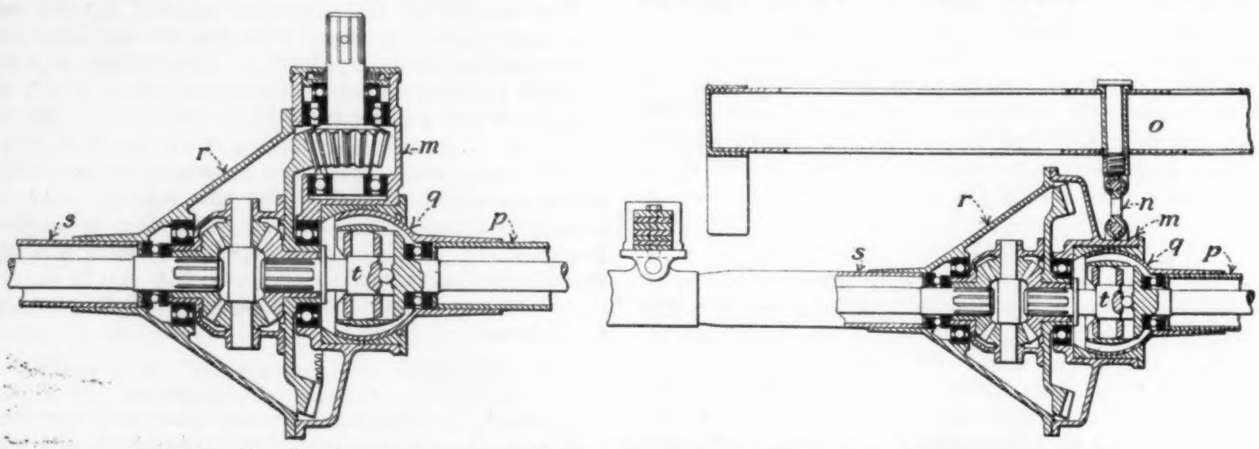


Fig. 15—End Elevation at the Left and Plan View at the Right of an Epicyclic Rear-Axle

The disadvantages of the ordinary rear-axle suspension are illustrated by Fig. 16, where the dotted line shows the movement of the ordinary live axle when the left road wheel is passing over a 4-in. obstacle.

The exact movement of the body cannot be determined on paper, but obviously the ideal arrangement is for the body to remain absolutely horizontal, so that the passengers may not be thrown from side to side. In Fig. 16 the body is purposely drawn stationary to show the relative movements of the two axles. It will be noted that the center point of the ordinary axle has been displaced sideways as indicated by the letter u. The springs have also moved sideways a distance v and w or alternatively the body must be thrown sideways, while with the jointed axle the road springs remain practically vertical. There can be little doubt that the independent motion of the road wheels, obtained by the use of a jointed axle, will provide greater comfort for the occupants of the car and the reduction of unsprung weight will considerably prolong the life of the tires. In the De Dion Bouton design the only advantage appears to be that of the reduction of unsprung weight, as the movement of the road wheels resembles that of an ordinary axle.

Worm Gear Design

Although the advantages and characteristic features of worm gear are now well understood, I have never yet come across any textbook which explains the real nature of the tooth contact between the worm and the wheel. Before discussing this subject in detail, the ground may be cleared by a few introductory remarks.

> Circular pitch is measured circumferentially along the pitch circle of the worm wheel
> Linear pitch is measured in a straight line parallel to the worm axis
> Lead angle is the angle between a worm thread and a line drawn at right angles to the worm axis
> Lead is the distance traveled by any point on the pitch circumference of the wheel for one revolution of the worm

Lead	= Linear pitch × Number of threads
Tangent Lead Angle	= Lead / (π × Pitch diameter of worm)
Pitch diameter of wheel	= (Number of teeth × Circular pitch) / π

In an ordinary worm gear the axes of the worm and the wheel are at right angles, and under these conditions

[2] See The Journal, July, 1917, p. 29.

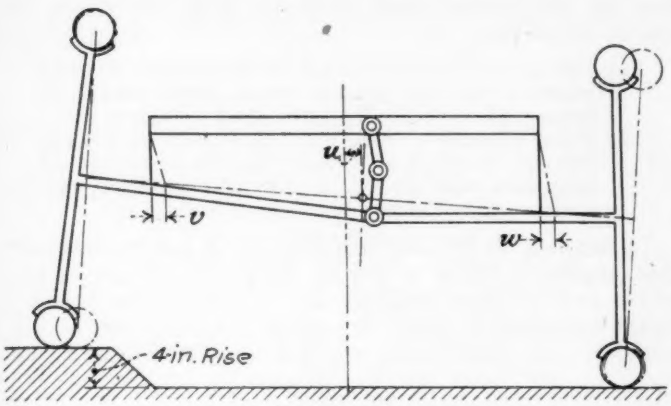


FIG. 16—DIAGRAM OF THE REAR-AXLE MOVEMENT IN PASSING OVER A 4-IN. OBSTACLE

the circular pitch of the wheel is equal to the linear pitch of the worm.

The gear ratio of worm gear is found by dividing the number of teeth in the wheel by the number of threads in the worm, yet, unlike spur or bevel gearing, the ratio is independent of the pitch diameters of the worm and the wheel. One concrete example will make this perfectly plain. Let a worm of 1.585-in. pitch diameter mesh with a wormwheel of 15.915-in. pitch diameter having 100 teeth of ½-in. circular pitch at 8.75-in. center distance. Then the gear ratio may be varied by varying the number of threads in the worm without altering the pitch diameters or the center distance. Some of the possible variations are given in Table 1.

TABLE 1—RELATION BETWEEN NUMBER OF THREADS IN A WORM AND THE LEAD ANGLE

Threads in worm	Gear ratio	Lead, in.	Worm angle, deg.	min.
1	100.0 to 1	0.5	5	44
2	50.0 to 1	1.0	11	21
4	25.0 to 1	2.0	21	53
6	16.7 to 1	3.0	31	04
8	12.5 to 1	4.0	38	47
10	10.0 to 1	5.0	45	07

In this table the pitch diameters and center distance remain unaltered. It will be seen that a large gear ratio, 100 to 1, necessitates a small lead angle, 5 deg. 44 min. and vice versa. The most efficient lead angle lies between 40 and 45 deg.

Some engineers calculate worm gears on the hit-or-miss principle. This is a mistake. The proposition is really very simple, if attacked in a systematic manner. Thus, required to design a worm gear with a ratio of 10 to 1, the size of the worm wheel being restricted to 16-in. pitch diameter on account of ground clearance.

$$\text{Lead} = (\text{Pitch diameter of wheel} \times \pi) / \text{Gear ratio}$$
$$= (16 \times \pi) / 10 = 5 \text{ in. approximately}$$

In other words, the lead *must* be 5 in., no matter what linear pitch, lead angle or pitch diameter of worm be chosen. The next most important factor is the lead angle. To obtain high efficiency select a high angle, say 40 deg. Then

$$\text{Pitch diameter of the worm} = \text{Lead} / (\text{Tangent of lead angle} \times \pi)$$
$$= 5 / (0.84 \times \pi) = 1.9 \text{ in.}$$

Hence a lead angle of 40 deg. cannot be used, because 1.9 in. is too small a diameter for such a large gear. Now ascertain the smallest diameter of worm shaft to withstand torque and bending, and select a pitch diameter to correspond, say 2.5 in. Then

$$\text{Tangent of the lead angle} = \text{Lead} / (\text{Pitch diameter of worm} \times \pi)$$
$$= 5 / (2.5 \times \pi) = 0.64$$

The angle having a tangent of 0.64 is approximately 33 deg. Thus, under the conditions given, the lead angle cannot exceed 33 deg., and the efficiency of the gear can be calculated accordingly.

The manner in which the lead angle varies according to the pitch diameter, with a given gear ratio and center distance, is illustrated in Table 2.

TABLE 2—RELATION BETWEEN THE LEAD ANGLE AND THE PITCH DIAMETER

Fixed gear ratio, 10 to 1 Fixed center distance, 8.75 in.

Wheel pitch diameter, in.	Worm pitch diameter, in.	Lead, in.	Lead angle deg.	min.
16.00	1.50	5.03	46	40
15.75	1.75	4.95	42	0
15.50	2.00	4.87	37	49
15.25	2.25	4.80	34	13
15.00	2.50	4.72	30	57
14.75	2.75	4.64	28	12
14.50	3.00	4.55	25	47

It need hardly be said that no gear should be selected without first consulting a maker's hob list in order that standard tools may be brought in.

When the shape of, or forces acting on, worm-gear teeth have been theoretically considered, it has been usual to take a linear section through the center of the worm at right angles to the wheel axis. On this axial plane it has been customary to make the shape of the gear teeth to correspond with those of a rack engaging with an ordinary spur, thus providing an involute tooth profile on this particular section. But what is taking place on adjacent parallel planes?

The shape of the teeth of a rack-shaped worm, on one of these corresponding parallel sections, is peculiarly curved, and the wheel teeth, on these planes, should be conjugate to suit, but this is impossible owing to interference. On these other planes the wormwheel teeth are concave, in order that they may wrap round the threads of the worm, so that corresponding sections, on either side of the axial plane, in no way resemble the involute shape of tooth. Hence it follows that the transmission

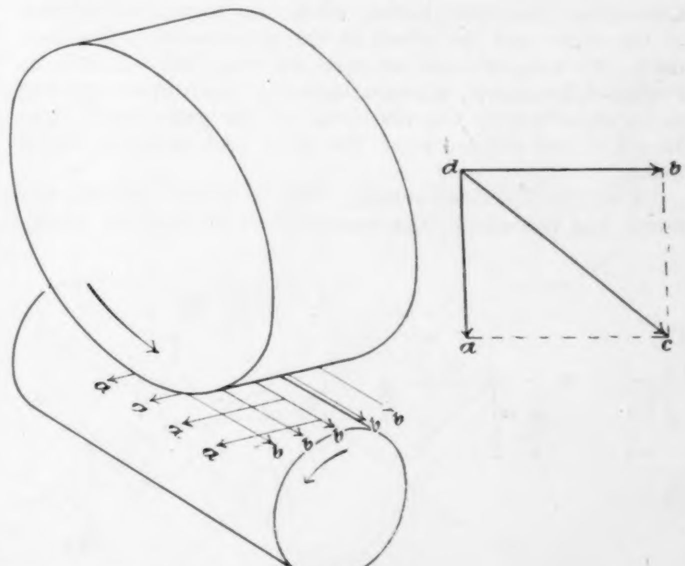


FIG. 17—DIAGRAM SHOWING THE RELATION BETWEEN THE TORQUE ON THE WORM AND THE WORMWHEEL AT THE LEFT AND THE RESOLUTION OF THE FORCES AT THE RIGHT

of true uniform velocity, which is a characteristic of the involute gear, applies only to a section on the axial plane where the worm section is that of a rack. The constructive problem of the nature of the tooth contact on these other planes has, it is believed, never before been properly investigated. It can, however, be successfully solved by the application of the principle of the parallelogram of forces which must hold good at every point where tooth contact takes place, and the application should be applied to every single phase of tooth contact, and not merely limited to one axial plane as has been the practice heretofore.

The pitch surfaces of the worm and the wheel are both cylinders, and can therefore only touch at one point. The torque on the worm can be represented by a force *a*, acting longitudinally anywhere on the pitch surface, and in a tangential direction, as shown in Fig. 17. In the same way the torque on the wheel can be represented by a force *b* acting in the same manner.

To obtain the transmission of uniform velocity between the worm and the wheel, it is necessary that the resultant force *c*, normal to the tooth surfaces at their point of contact, shall be capable of being resolved into two components, *a* and *b*, both of which must always be tangential to their respective pitch cylinders and at right angles to their axes, these three forces all lying, of course, on the same plane. For if the resultant *c* can be resolved into two components either of which do not touch their respective pitch cylinders, the instantaneous torques on the two gears will not correspond to the velocity ratio. But the velocity ratio is determined by the threads of the worm and the teeth of the wheel, which is obviously a constant quantity; hence, when the respective torques of the worm and the wheel do not correspond to the gear ratio, the transmission of true uniform velocity will be impaired, the slight accelerations and retardations having to be absorbed by the elasticity of the gear teeth, thus lowering the efficiency of the gear and causing undue wear.

To secure uniform velocity transmission between the worm and the wheel, the constructive problem of building up the correct tooth contours may, therefore, be stated as follows:

(1) Select a series of resultant forces capable of being resolved into components which must always be tangential to their respective pitch cylinders
(2) From a series of such resultants build up a tooth contour, working on the well-known fact that all resultants must always be normal to the tooth surfaces at their respective points of contact

In drawing at the right of Fig. 17, *a* and *b* represent the tangential forces acting on the pitch cylinder of the worm and the wheel respectively about the point *d*, and *c* is the resultant of these, acting in the plane containing *a* and *b*. The relation between *a* and *b*, being determined by the ratio of the gears, is bound to remain constant, so that the angle which *c* makes to the axis of the worm will also remain constant.

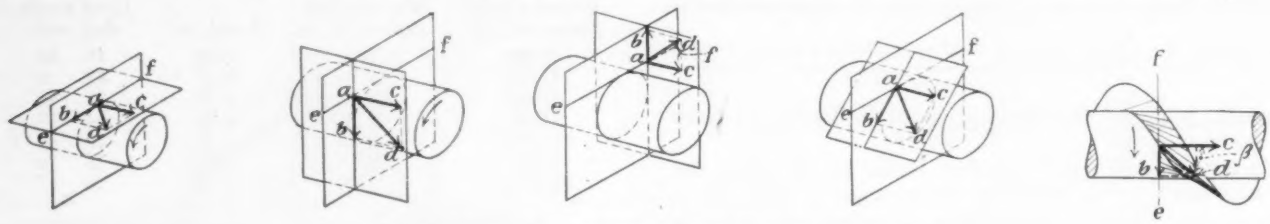


Fig. 18—Diagram of Forces Acting in Various Planes
From Left to Right in a Horizontal Plane, the Near Side of a Vertical Plane, the Far Side of a Vertical Plane, an Inclined Plane and the Series of Resultants Obtained

Determination of Points of Contact

At the left of Fig. 18 is shown a simple application of these forces, the point *a* being the contact point of the two cylinders lying on a "central plane" at right angles to the worm axis and containing the wheel axis. In this particular case the plane *bcd* is tangential to both cylinders. The next drawing represents a view of the same plane when moved through 90 deg. round the worm pitch cylinder, the point *a* still being on the pitch cylinder of the wheel and also on the central plane so that *c* may still remain tangential to the wheel. The middle diagram is a similar view when the plane is moved around the pitch cylinder in the opposite direction.

In all these three cases it will be observed that *c* is tangential to the wheel cylinder, and that both *b* and *d* are, in every case, tangential to the worm cylinder. It will be further noted that the point *a* in each case lies on the line of intersection of the wheel cylinder and the central plane. When these conditions are fulfilled, and the angle β remains constant, three points of contact are obtained.

It is now necessary to ascertain all the possible intermediate positions in which the fundamental conditions still obtain. Let *ef* be a line on the central plane tangential to the worm cylinder. Then the requisite conditions are fulfilled if the center *a* of the forces always lies on *ef*, and the plane is always tangential to the worm cylinder and in such a position that the force *b*, acting at right angles to the axis of the worm, is always tangential to its cylinder, the same relation holding good between *c* and its wheel cylinder. Such an intermediate example is illustrated in next to the last drawing, and that at the extreme right shows a series of resultants forming a "zone of contact" which contains all the possible points of contact and provides for the correct relation between *b* and *c*. As the resultants *d* are tangential to the worm cylinder, it follows that they only touch at one point; hence beyond this point they project outward and

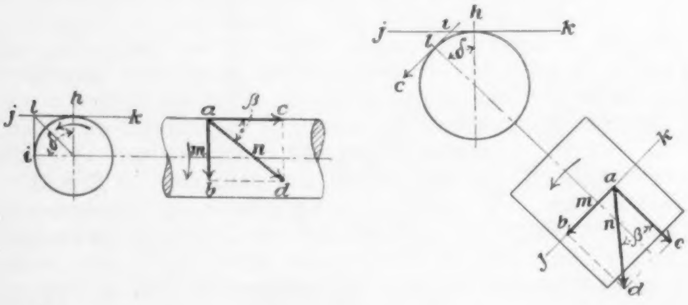


Fig. 19—Determination of a Point of Contact on the Pitch Cylinder at the Left when δ Equals 90 Deg. and at the Right when It Is Less than 90 Deg.

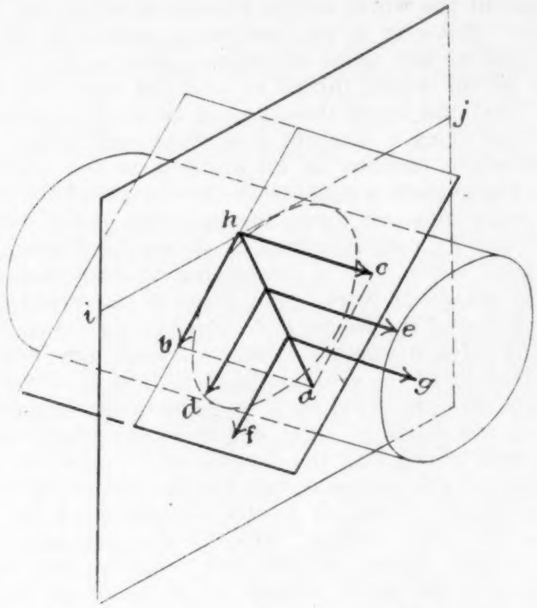


FIG. 20—FORCES ACTING IN AN INCLINED PLANE WITH A SERIES OF COMPONENTS

provide for points of contact outside or beyond the periphery of the worm cylinder. These external points of contact necessitate the building up of a tooth, the contour of which is controlled by the zone of contact, the latter being normal to the tooth surfaces at their respective points of contact. From the above it will be obvious that the zone of contact does not lie on the periphery of the worm cylinder, but stands proud in the form of a twisted ribbon. It is, in fact, a series of innumerable straight lines which, combined together, provide a curved surface, all these lines being tangential to the worm cylinder and lying at a constant angle β to the worm axis in addition to cutting the line *ef* on the central plane.

In Fig. 19 it will be obvious that one point of contact is on the central plane at the point of contact *h* between the two cylinders. Move the contact point through an angle δ equal to 90 deg. Then the point of contact will have moved in the end view to the point *i*.

In the same view draw *jk* tangential to the worm cylinder at the point *h*, and draw *il* at right angles to it. Project a side view looking in the direction *jk* and let *a* be the intersection of the forces *b* and *c*, as before. The point *a* lies on the line *jk* which is contained by the central plane. Draw the resultant *d* and project *i* until it cuts *ab* at *m* and intersects the resultant *d* at *n*. Then *n*, being on the resultant *d*, and also on the pitch cylinder, is the position of the point of contact after it has been moved through 90 deg., and the length *mn* is its distance from the central plane.

Then

$$mn = am \cot \beta$$

and

$$am = li = \text{Radius} \times \tan \tfrac{1}{2}\,\delta$$

therefore

$$mn = \text{Radius} \times \tan \tfrac{1}{2}\,\delta \cot \beta$$

At the right of Fig. 19 the angle δ is less than 90 deg. Draw *jk* as before and from *i* draw *il* tangential to the worm cylinder at the point *i* and cutting *jk* at *l*. Project a view on a plane parallel to *il* and project *l* to cut *jk* at the point *a*. From *a* draw the forces *b*, *c* and *d* as before. Project *i* until it cuts *ab* at *m* and intersects the resultant *d* at *n*. Then *n* is the point of contact and *mn* its distance from the central plane.

Then

$$mn = \text{Radius} \times \tan \tfrac{1}{2}\,\delta \cot \beta$$

as before.

As *a* is the single force which produces the same effect as the combined action of the two forces *b* and *c*, and as *a* may be resolved into any two forces such as *d* and *e* or *f* and *g*, it follows that *b* and *c* may act at any point in the same plane along *a* as shown by the diagram in Fig. 20. Hence the contact point between the worm and wheel can lie anywhere along the resultant *a*, and the effective result will be the same as if the components originated from *h* and the line *ij*. It is therefore possible to have contact outside the worm cylinder at any point along *a*.

Although the contact point lies along a certain resultant, the position of this point will vary according to the rotation of the worm. The zone of contact will always remain stationary, owing to the fact that the positions of the resultants are definitely determined by their intersections with the stationary line *ij*, the latter being independent of any rotary movement of the worm gear. The actual points of contact will be the intersection of the worm tooth and the zone. It is therefore necessary to ascertain, in accordance with the rotation of the worm, the location of the points of contact along the resultants *a* on any outside portion of the worm thread.

Let *m* (Fig. 21) be any such point located at any radius *nm* from the axis of the worm and making any angle δ with a plane *no* containing the worm axis and at right angles to the wheel axis.

From *m* draw *mp* tangential to the worm pitch cylinder in a direction opposite to the supposed rotation of the worm, so that *pm* represents the force *q*. This line intersects *rs* at *t*. Project a view on a plane parallel to *pm* and complete the construction as in the case of Fig. 19. From *m* draw *mv* parallel to *rs* meeting *no* at *w*. Draw *wx* parallel to *mb* intersecting the line *rs* at *x*. Then, as before, *y* is the new point of contact and *zy* its distance from the central plane.

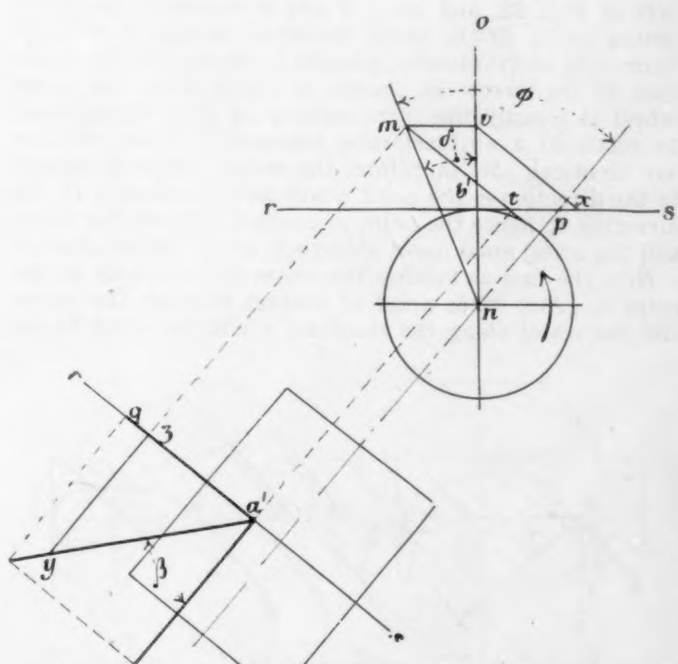


FIG. 21—DETERMINATION OF THE POINT OF CONTACT OUTSIDE THE PITCH CYLINDER WHEN δ IS LESS THAN 90 DEG.

Then
$$zy = a'z \cot \beta$$
and
$$za' = tm = vx$$
Let
$$\angle pnm = \phi$$
Then
$$\angle pnv = \phi - \delta$$
but
$$\angle pnv = \angle vxb'$$
Therefore
$$\angle vxb' = \phi - \delta$$
Now
$$xv = vb' / \sin (\phi - \delta)$$
but
$$vb' = vn - nb'$$
and
$$vn = nm \cos \delta$$
Therefore
$$vb' = nm \cos \delta - nb'$$
Hence
$$xv = (nm \cos \delta - nb') \div \sin (\phi - \delta)$$
As
$$xv = a'z'$$
therefore
$$zy = [(nm \cos \delta - nb') \div \sin (\phi - \delta)] \cot \beta$$
so that
$$zy = \cot \beta \, [(\text{Radius of contact point x} \cos \delta) - \text{Pitch of radius cylinder}] \div \sin (\phi - \delta)$$
Note that when the point of contact is on the pitch cylinder
$$zy = \frac{\text{Radius of pitch cylinder} \times \cos (\delta - 1)}{\sin (0 - \delta)} \cot \beta.$$
$$= \frac{\text{Radius of pitch cylinder} \times \cos (\delta - 1)}{\sin - \delta} \cot \beta.$$
$$= \text{Radius of pitch cylinder} \times \tan \tfrac{1}{2} \delta \cot \beta$$
as already shown in connection with Fig. 19.

Straight Line Generation

Let *ab* be the surface of the worm thread moving in the direction of the arrow as shown in the diagram at the left of Fig. 22, and let *c*, *b* and *e* represent the forces acting on it. If the worm thread *ab* be moved at a uniform rate longitudinally, parallel to its axis, in the direction of the arrow as shown, it would drive the worm wheel in exactly the same manner as if it were caused to rotate at a uniform rate, because all linear sections are identical. If, therefore, the worm rotate uniformly in the direction *c*, the point *a* will move uniformly in the direction *d*; hence the point of contact between the worm and the wheel must move uniformly along the resultant *e*.

Now the line *ae* touches the worm cylinder only at the point *a*. Any other point of contact between the worm and the wheel along the resultant *e* will therefore be on a portion of the worm thread projecting above the worm cylinder. But *e* is in the horizontal plane defined by *d* and *c*, and as any point of contact along *e* is an intersection of the worm thread *ab* and the resultant *ae*, it follows that the worm thread must be of such a contour that it lies along a straight line *ab* at right angles to *e* and therefore inclined at an angle β to the plane *fg*. Clearly the angle β is equal to the lead angle of the worm.

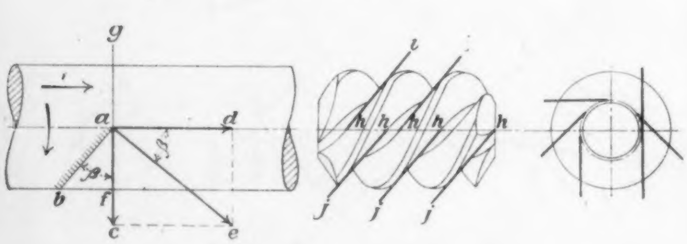


Fig. 22—Diagram at the Left Showing How the Straight Line *ab* Lying on the Thread Contour of the F J Worm Insures Uniform Velocity Transmission and at the Right a Plan of the F J Worm Indicating the System of Straight-Line Generation

The other diagram shows the positions of the straight lines *hi* and *hj*, corresponding to *ab* on the threads of a left-handed worm. It is interesting to note that, with this new design of worm gear, there is no thread below the pitch line of the worm, and consequently throat diameters and pitch diameters of worm wheels are identical.

The threads of the ordinary parallel type of worm gear are made straight-sided on a linear section through the center of the worm at right angles to the wheel axis.

It is well known that the tangent of the circular pressure angle at any radius equals the tangent of the linear pressure angle multiplied by the cotangent of the lead angle at the same radius. The circular pressure angle is, of course, shown in the end view of the worm, tangential to the tooth contour at its point of contact.

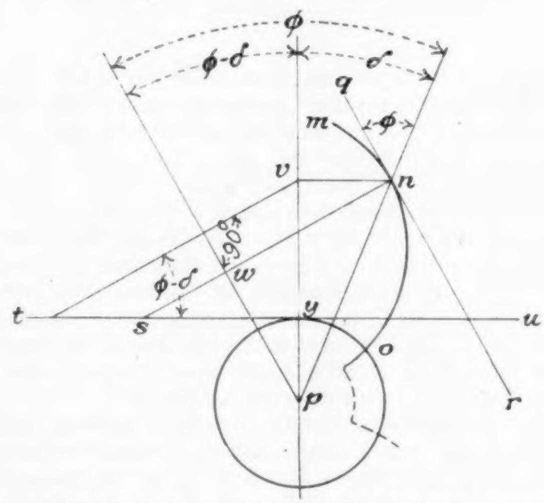


Fig. 23—Determination of Points of Contact outside the Pitch Cylinder of the Ordinary Type Worm Gear

To draw a diagram of the zone of contact of the ordinary type worm gear it is necessary to ascertain the distance of various points of contact at various radii from the central plane. These may be ascertained by drawing a diagram similar to that shown in Fig. 21. Thus, in Fig. 23 let *mno* be the end view of a portion of the worm thread from which it is required to ascertain the distance of the point of contact *n*, on any radius *pn* situated at any angle δ from the central plane. Draw *qnr* at the circular pressure angle ϕ to the radius *pn*. From *n* draw *ns* perpendicular to *qnr*. Then *ns* represents the normal to the tooth at its point of contact.

Now *ns* cuts the line *tu* at *s*. From *n* draw *no* parallel to *tu* and *vt* parallel to *ns*. Then the angle *vtu* equals the angle $nsu = \phi - \delta$. As before the distance x equals *ns* multiplied by the cotangent of the lead angle on the radius *pw*, but
$$ns = vt = vy / \sin (\phi - \delta)$$
and
$$vy = ns \cos \delta - ey$$
therefore
$$x = [ns \cos \delta - ey \div \sin (\phi - \delta)] \text{ cotangent of lead angle on radius } pw$$

From this formula the curves shown in the left half of Fig. 24 have been plotted, and from the formulas already given in connection with Figs. 19 to 21 the graphs shown in right half have been plotted. These show the lines of contact along the zone for the F J worm gear.

COMPARISON OF THE TWO TYPES OF WORM GEAR

The two portions of Fig. 24 should be carefully compared. In left half, which shows the lines of contact for the ordinary type of worm gear, the zone of contact is actually interrupted near the central plane, and almost the entire contact takes place on the approaching side of the wormwheel, which means that if the worm be placed in engagement with the wheel, contact between their teeth takes place on the extremities of the worm, when, in many cases, the center teeth have practically no contact. There is also a duality of the lines of contact, which, during the revolution of the gear, gradually travel towards each other, meeting just beyond the central plane where contact entirely ceases.

In the right half of Fig. 24, which shows the zone of contact for the F J worm gear, it will be noticed that the lines of contact are regular and uniform, with no duality and no objectionable interruption. The left half demonstrates the very imperfect form of tooth contact obtained from the ordinary type of worm gear, which is straight-sided on the linear section. In the year 1913 both F. J. Bostock and myself knew of these defects. The solution and the remedy were, however, discovered by Mr. Bostock, and it was entirely due to his efforts, in conjunction with the facilities afforded by David Brown & Sons, that this new form of F J worm gear has been evolved. I had the privilege, however, of watching the mathematical development of the present invention, which entailed great labor and occupied many months, a brief outline of which has now been made public for the first time.

The difference between the ordinary and the F J type of worm gear can be best illustrated, to those who are not keenly interested in mathematics, by taking a concrete example of each case as shown in the four sections of Fig. 25. These illustrations show two plan views of each type of worm, together with a sectional view of each worm in mesh with its wormwheel just above. The two views in the left half show the nature of the contact between an ordinary type of worm and wheel, that at the extreme left showing the worm in such a position that the drive is taken by the two threads *a* and *b*, while the next one shows a different position, the worm having been rotated through an angle of 45 deg., thus causing the thread *a* to carry the entire load. The ribbon-like area, outlined on the plan view and stretching across the

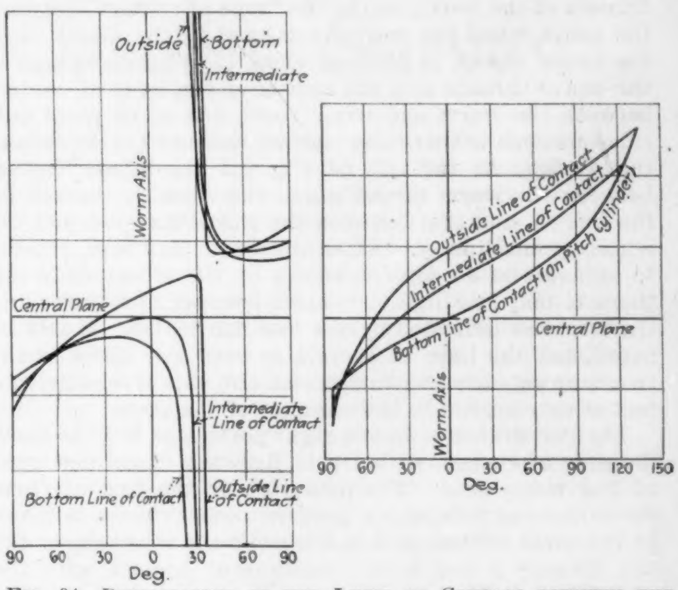


FIG. 24—DEVELOPMENT OF THE LINES OF CONTACT BETWEEN THE WORM AND WORMWHEEL AT THE LEFT WITH THE ORDINARY TYPE OF WORM GEAR AND AT THE RIGHT WITH THE F J TYPE OF WORM GEAR

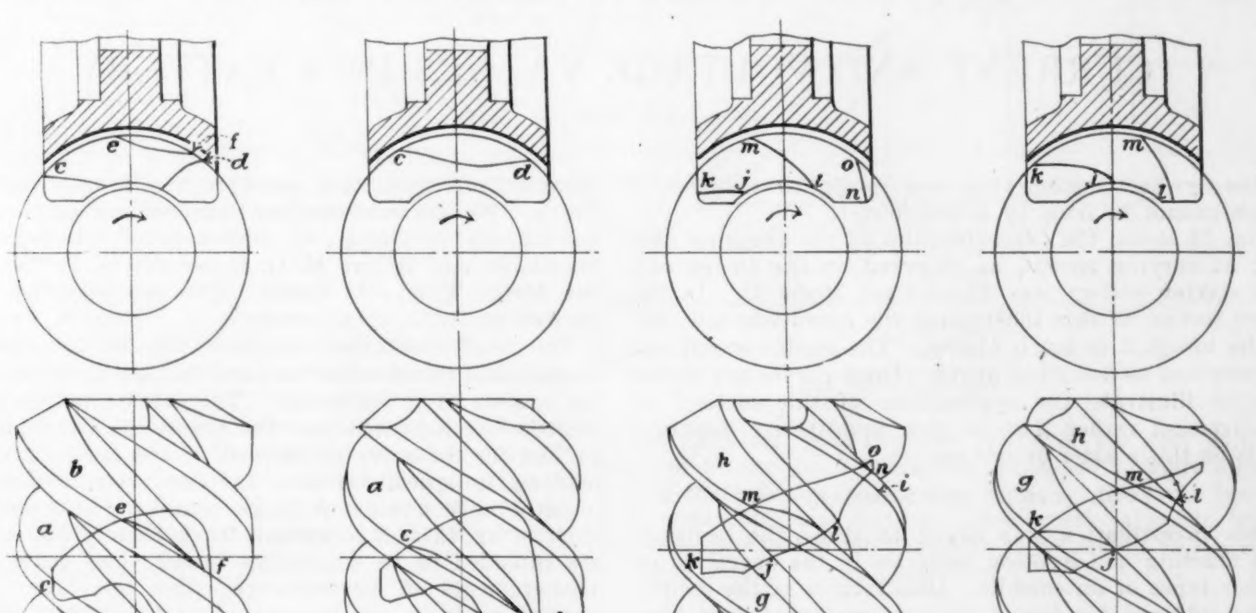


FIG. 25—DIFFERENCE BETWEEN THE ORDINARY AND THE F J TYPES OF WORM GEARS
At the Left the Zone of Contact between the Ordinary Type of Worm and Wormwheel Is Shown and in the Next Section to the Right Is Portrayed the New Position of the Worm Threads after a Rotation of 45 Deg. The Two Views in the Right Half of the Illustration Are the Corresponding Positions of F J Worm and Wormwheel

threads of the worm, marks the "zone of contact" between the gears when the worm is rotated in the direction of the arrow shown in the end view. The intersections of the worm threads and the zone give the lines of contact between the worm and wheel teeth, and at no point outside this zone is there any contact between the worm and the wheel. At the left of Fig. 25 the actual contact between the worm thread *a* and the wheel is marked by the line *cd*, and that between the worm thread *b* and the wheel by the line *ef*. After the worm has been rotated to an angle of 45 deg., as shown by the second drawing, there is only one line of contact between the worm and the wheel as indicated by the line marked *cd*. It will be noted that the lines of contact in both end views in the two drawings are unsymmetrical, and this irregular contact is detrimental to the running of the gears.

The two drawings in the right portion of Fig. 25 show the zone of contact with David Brown & Sons' new type of F J worm gear. The plan view in the first of these shows the worm in such a position that the drive is taken by the three threads *g*, *h* and *i*, while the other shows the two threads *g* and *h* in simultaneous contact with the wormwheel. The actual lines of contact between the worm and the wheel in the first case are marked *jk*, *lm*, and *no*, while in the other, after the worm has been rotated through an angle of 45 deg., the new lines of contact are shown by the line *jk* and *lm*. With this design of worm gear the regularity of the lines of contact as shown in the end view is in marked contrast to that of the contact lines shown in the other half of the illustration.

The worms illustrated in Fig. 25 are as alike as possible, both types having four threads, the only real difference between them being in the shape of the tooth contour. In both cases whenever the worm is revolved through an angle of 90 deg., the line of contact *jk* will sweep across the zone of contact until it takes up the position of *lm*, because when a four-threaded worm moves a quarter of a revolution or 90 deg. the thread *g* will naturally take up the position of the thread *h*. In the F J system it will be seen that the point *j* at the root of the worm in the end view falls into the position *k* after a quarter of a revolution as shown at the extreme right of the illustration. Thus, the actual contact travels in the same direction as the worm, and this new action between the teeth of the gears reduces the ordinary rubbing velocity to a minimum, which decreases frictional losses and consequently increases the efficiency of the drive to a very marked degree.

With the ordinary parallel type of worm gear, however, the point of contact *d* actually moves in the opposite direction to the rotation of the worm to the point *f*, thereby increasing the rubbing velocity. One of the peculiar characteristics of the ordinary type is that the extremities of the lines of contact as shown in the plan view of the worm at the extreme left, travel from the position *c* and *d* toward each other until they meet and vanish just beyond the point *e* and *f*.

The end view of the F J system in the third drawing shows the point *k* always moving from left to right, in the same direction as the rotation of the worm, while with the ordinary type the point *d* moves very slightly from right to left, actually against the rotation of the worm. The high rubbing velocity which occurs on the points *d* and *f* together with the converging lines of contact which induce a concentrated load, all tend to produce the worst possible conditions on the leaving side of the wormwheel. This explains the well-known fact that when a worm gear of the ordinary type is overloaded, or is imperfectly lubricated, pitting first takes place on the leaving side of the wheel, and on this side only, while those portions of the teeth on the entering side remain unmarked. It is believed that this is the first time that this phenomenon of uneven wear on the teeth of the wormwheel of the ordinary parallel system has been fully explained.

CURRENT AND VOLTAGE VALUES IN A BATTERY

(*Concluded from page* 327)

of the flywheel system from one revolution to another, which cannot be done by a tachometer.

Fig. 17 shows the characteristics of the charging current at varying speeds, as observed on the Dodge car. The starter system was North-East Model D. In the upper section of this illustration the speed was low, but in the lower it is much higher. The engine speed can be computed as described above. These curves are shown here to illustrate the applications of this method of measurement rather than to give quantitative measurements on this starter or system.

Conclusions and Summary

This investigation was begun to study the demands upon starting and lighting batteries in the operation of various types of automobile. Illustrations of the oscillograms obtained for five of the cars measured have been included in this paper. Some of these cars belong to private individuals and some to the Motor Transport Corps. We acknowledge our indebtedness to them and particularly to Dr. H. C. Dickinson of the Bureau of Standards and Majors M. O. Boone and G. H. Totten of the Motor Transport Corps. The special camera was devised by Dr. J. C. Karcher.

The results obtained enable us to determine the instantaneous values of current and voltage when the starting system is in operation. The interpretation of the records has indicated also the possibility of using this method for the study of lubrication and engine problems relating to speed, friction, ignition, compression, distributor action, etc. A large number of oscillograms illustrating these applications have been given. These are intended to be suggestive rather than quantitative measurements of performance, since the observations were all made on cars in running condition, without fixed orifices on the carbureter or a constant-speed control.

Third Semi-Annual Gasoline Survey

THE first survey of fuel gasolines sold throughout the United States was made by the Bureau of Mines in 1915. This was followed by another in 1917 and a third in April, 1919, which showed that the gasoline had become notably less volatile during each 2-year interval. To ascertain whether this change was continuing semi-annual surveys were made in January and July, 1920, and in January, 1921. In the January, 1920, survey it was found that the average volatility of the gasoline was practically identical with that tested in April, 1919. The survey made in July, 1920, the results of which were given in THE JOURNAL,[1] showed a very marked decrease in the volatility but as it is a matter of common knowledge in the petroleum industry that the volatility of gasoline sold in the summer months is less than that of the fuel made and sold in the winter, part of the change was attributed to this fact.

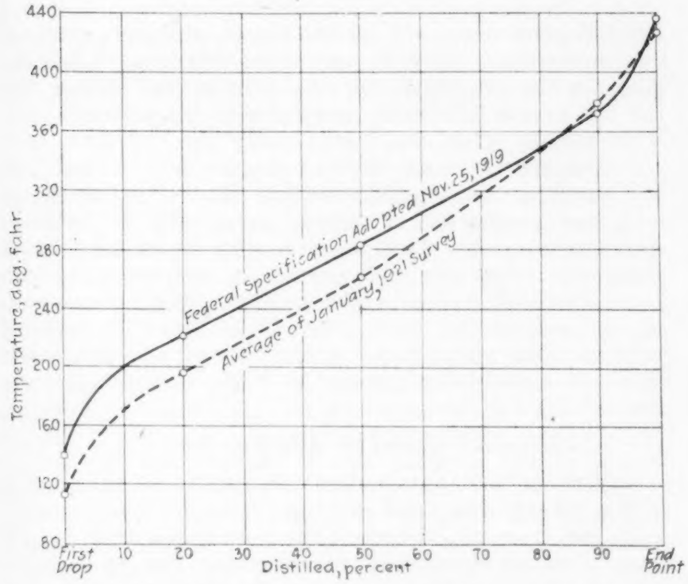


FIG. 1—DISTILLATION CURVE OF THE AVERAGE OF THE SAMPLES OBTAINED IN THE THIRD SEMI-ANNUAL GASOLINE SURVEY AND ONE BASED UPON THE FEDERAL SPECIFICATION ADOPTED NOV. 25, 1919

In the recently completed survey 115 samples were collected and analyzed. It was found that the average boiling point of these samples was 263 deg. fahr. as compared with 264 a year ago, which shows that the average gasoline marketed at the present time is fully as volatile as that sold a year ago. A noticeable change in the character of the product has, however, occurred, the initial boiling and 20 per cent points being lower than a year ago, while the 90 per cent and end-points are higher which indicates a greater proportion of gasolines made by blending casinghead or natural gas-gasoline and naphtha. This change in the character of internal-combustion engine gasoline is brought out in the accompanying illustrations. Fig. 1 shows a distillation curve based on the average figures of the present survey together with a similar curve based on the Federal specification adopted Nov. 25, 1919. In this connection it will be noticed that the distillation curve for the recent survey is higher than the specification curve at the 90 per cent point. Fig. 2 presents the upper ends of the curves of the averages of the three surveys and the Federal specification previously mentioned. This illustration brings out in a striking manner the change noted from January to July, 1920, which was due particularly to the normal change from winter to summer quality and also to a permanent change in the character of the gasoline. The increase in the 90 per cent point probably means that the refiners are including more high boiling material in the gasoline while at the same time they apparently are getting closer fractionation in the distilling process as the end-point is not being increased as much as the 90 per cent point.

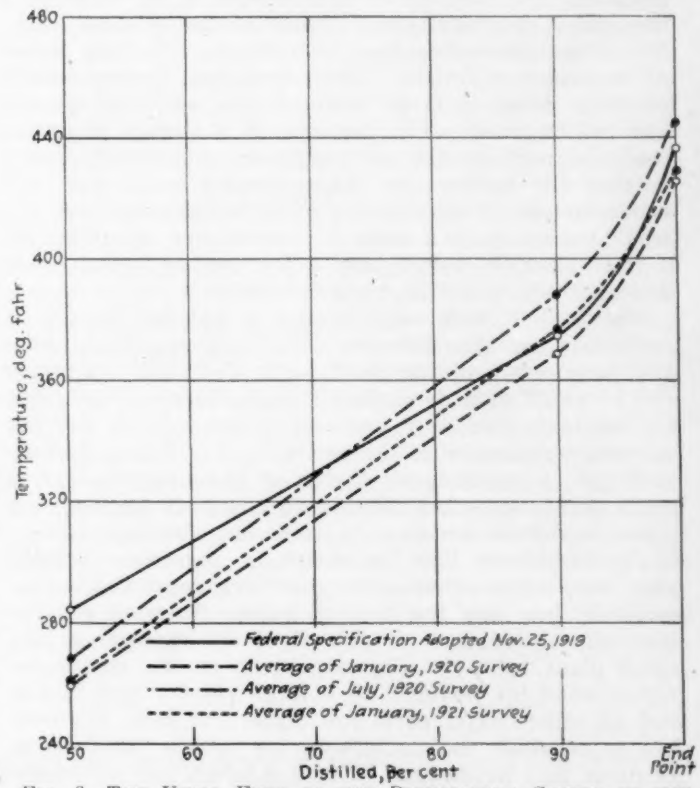


FIG. 2—THE UPPER ENDS OF THE DISTILLATION CURVES OF THE AVERAGE OF THE THREE GASOLINE SURVEYS AND THAT SPECIFIED BY THE FEDERAL GOVERNMENT

[1] See THE JOURNAL, September, 1920, p. 300.

The Body Engineer and His Relation to the Automotive Industry

By Kingston Forbes[1]

Annual Meeting Paper

In choosing the title of this paper it was hoped that a note could be struck which would bring to the attention of the industry the breadth and scope of body engineering and outline the way this side of the industry can be considered and developed. Body engineering must, of course, depend on mass production or big business for its greatest encouragement. In small-scale production small items can be handled very easily, but in large productions they are of tremendous importance. If 1000 cars are scheduled to be made in a day and a shortage occurs in one of the smallest items, the entire production may be held up, incurring a loss of thousands of dollars. This emphasizes the importance of every detail in large business in a way that no one can fail to grasp. For instance, if a change in design could be made by the body engineer that would permit cutting the leather for the trimming to 15 per cent waste instead of 20, a saving of $1,000 and over per day would be made in a daily car production of 1000. In a small shop or custom shop a few feet of leather more or less would not make much difference.

The field of body engineering is broader than it is ordinarily considered to be. The body engineer's relation to a body building plant, large and small car plants and a custom shop, demands different classes of engineers. In the main the body engineer is responsible for the external appearance of the entire car. If it is a custom-built job, a preliminary sketch of the complete car is made, and very often this is all the body builder, top maker and trimmer have to work on; the car is made to look as much like the sketch as possible. A body plant very often submits designs for a complete car, but generally has only the body to build. To work out his ideas or combination of ideas the body engineer of the small plant relies to a great extent on the companies which build his bodies. In a large plant where bodies and all other metal parts are made, the body engineer has to consider the manufacturing details involved in all parts that he designs. There is a distinct difference between the mechanical side of the automobile and the general appearance or the artistic side. One would not ordinarily combine the story writer and the illustrator in more than a cooperative spirit. The success of the story does not depend upon the illustrations, or vice versa. But having a good story properly illustrated gives a wider field for its sale. So it is with a car; the mechanical condition and limitations have to be taken in hand by the body engineer. As a first qualification the car must be artistic. This is demonstrated by the 1921 cars. The body engineer of a company specializing in custom work must apply artistic principles in every body he designs; each car demands individuality and draws heavily on his power of creation. In the case of large production, a body designer has to satisfy 100,000 people with perhaps one model. We know that the tastes of 100,000 people are not all the same, although some of our movie stars have an unlimited following. The design for the 100,000 is not the most stylish design, but the one that will be most acceptable to the majority.

Customers often say that a given car does not quite suit and specify some favored characteristic. But few will agree on any specific design. But if a car of established popularity is shown, practically all will be satisfied with it. The point I wish to make is that simplicity of design and absence of jarring notes can be evolved only by painstaking effort. The layman cannot appreciate the work behind the smoothly finished product. The effort is not evident as with carvings and intricate embellished curves on historic buildings and churches.

Conflict Between Art and Economy

Art as applied to an automobile has to be manifested in the arrangement and shaping of sheet metal or other units on frames. Whether the result required be accomplished in economical manufacture has to be considered. The production of one thousand or more cars a day does not permit fancy hand decoration or carvings. Art has to be satisfied by huge presses and metal-forming machines. To achieve results, the practical sense of the body engineer must be as keen as his artistic ability; they must be coordinated to avoid disappointment. While there are definite conceptions upon which the artist bases his work, his success does not depend upon geometrically arranged lines, nor can the composition of his pictures be worked out with a slide rule. The mechanical side of the car is amenable to slide-rule practice, but the body lines are not. This is one reason body engineering has an indefinite position in the industry.

In large production it is not possible to control the metal parts in very fine degree, owing to variation in the grades of metal and the fluctuations in the operation of the presses. The upholstering, top design and painting, including enameling, all have a bearing on the final results. The main trades involved in body engineering are wood-working, sheet-metal working, metal machine-work, brace and hardware trimming, top building, painting and enameling. The body engineer should be familiar with all these trades. None of them can be learned by correspondence courses. In fact, there are practically no schools or instruction books covering the modern phases of the work.

A body engineering department can be classified in six main divisions.

(1) Body construction, open and closed
(2) Sheet metal, body metal, fenders, hood, radiators, etc.
(3) Trimming
(4) Top building
(5) General hardware
(6) Painting and enameling

[1] M.S.A.E.—Assistant body engineer, Buick Motor Co., Flint, Mich.

All the arts pertaining to the six divisions dovetail into one another and must have weight in the preliminary design. For instance, the radiator and hood can be considered the starting point for the body design; when these are established the main body construction is worked out from the dash or cowl-line back. The exterior lines of the body must be pleasing to the eye; at the same time the passenger capacity has to be ample and the comfort adequate. Satisfactory trimming has to be arranged for. Comfort depends upon leg-room, body-room and positions and well-arranged cushions and back springs with soft padding with suitable cloth, plush and leather covering. Passing on to the top, if it is an open body, the lines and windshield must be considered to permit a top to be made that will give proper protection and at the same time be pleasing in appearance and of course harmonize with the rest of the car.

The fenders and side aprons and radiators and mudpans can add or detract much from a car's appearance, and must be worked out to blend with the other larger elements in car craftsmanship. Under general hardware come numerous small parts such as window regulators, door-locks, windshield hinges, not very large in themselves but important in providing ease of operation and satisfactory service. What is more annoying on a car than defective locks, rattling doors and hard-working or leaky windshields? Last but not least comes the painting. When this is done properly it adds tremendously to the final results. The panels, molding and corners should be made so that painting will be simplified. Sprays and flowing operations are used in modern mass-production methods; bad corners, moldings and holes will interfere seriously with the paint and cause varnish and dirt runs. If it is planned to have molding in color different from that of the main panels, it must harmonize and not produce discordant lines.

Need for Attention to Details

I have endeavored to indicate the breadth of the body engineering field. As the production increases, accuracy in details becomes more and more necessary. An organized department is required to handle this work. The grouping previously referred to can be made into department divisions, controlled by a separate engineer if the amount of work warrants it, with one or more men to keep the work in progress. Also a general drafting force with chief draftsman and checker are required.

Modern accounting and production demand minute information about every piece that goes to make up a car, and this entails a great amount of detail drafting work. Every piece of wood, top and side-curtain material, reinforcement, ragboards and wadding, trim material, leather, artificial leather, binding, ounce of hair, tacks, nails, and every screw, nail and piece of hardware mean that engineering information is required with the blueprints and specifications. The old method was to make paper patterns of all of the parts and let the manufacturing departments control their own work; whenever duplication of parts was required, additional paper patterns were made and sent out. Long ago it was found that no progress could be made in manufacturing without proper engineering records and blueprints.

I venture to say that there are several modern automobile plants that have no definite engineering control of the material purchased and fabricated in the groups outlined. This material runs into millions of dollars per year.

While the art of coach-building is as old as the ages, it was brought to a manufacturing basis only a few years ago when buggy production hit its high mark. The advent of the automobile brought entirely new problems. The automobile body engineer is a recent recruit in the engineering profession. His importance can be measured by his designs and by his control of body materials and their fabrication. It is not sufficient that a beautiful and readily marketable design be produced; it must be possible to make it economically and without waste of material. The future holds big opportunities for the body builder and engineer. Competition will be keener than ever, not only among the body builders, but among the car builders. The automobile competition will be the body engineer's opportunity. With the stabilizing of chassis construction, the external body and allied construction will become one of the biggest factors in marketability and the stimulating of sales.

There is opportunity for bringing the materials used in body construction to definite standards. A few of the items that could be considered seriously in this connection are lumber specifications, cushion-spring wire, fabricated cotton hair, burlap, imitation leather, top materials, webbings, closed body and windshield glass, automobile hardware, body bolts, curtain fasteners, bow sockets, top hardware, bow bendings, back curtain lights and door-handles.

DECEMBER REFINERY STATISTICS

THE production of gasoline for the month of December, 1920, was 464,393,356 gal. according to the monthly report of refinery statistics compiled by the Bureau of Mines, compared with 452,642,125 gal. in November, 1920. The average daily rate of production in December was 14,980,431 gal., as compared with 15,088,071 gal. in November and 10,827,729 gal. in December, 1919. The quantity of gasoline stored in the various refineries on Dec. 31, 1920, was 462,381,837 gal. as compared with 354,835,764 gal. on Nov. 30, 1920, and 446,793,431 gal. on Dec. 31, 1919. The stocks on hand at the various refineries scattered throughout the United States at the end of December were approximately 108,000,000 gal. more than on Nov. 30, 1920, and 16,000,000 gal. more than on Dec. 31, 1919.

Gas and fuel oil was the only one of the minor petroleum products to register an increase in the total production, the figures being 859,131,359 gal. for December and 822,638,305 gal. for November. The production of kerosene in December amounted to 210,668,109 gal. against 214,804,177 gal. in November. In the month of December 90,894,798 gal. of lubricating oil was produced as against 91,180,007 gal. in the month of November. The stocks of kerosene on hand at the end of December were 393,070,923 gal. as compared with 398,991,592 gal. on Nov. 30, 1920. At the end of 1920 the stocks of gas and fuel oil amounted to 837,404,414 gal. as compared with 808,802,516 gal. on Nov. 30, 1920. The stock of lubricating oils stored at the various refineries on Dec. 31, 1920, amounted to 160,522,477 gal. against 142,180,775 gal. one month previous.

In the month of December 328 refineries with a daily capacity of 1,174,395 bbl. of crude oil were in operation. This represents an increase in the number of refineries of 2 and 16,100 bbl. in the daily capacity as compared with the previous month.

High-Speed Engines of Small Piston Displacement

By Louis Chevrolet[1] and C. W. Van Ranst[2]

Indiana Section Paper *Illustrated with* Drawing and Photographs

FUEL economy is one important reason for the high-speed engine of small piston displacement. Gasoline was little thought of 25 years ago; the idea that some day we might be without it was a matter of small interest. To-day, conditions have changed. The automobile has advanced beyond all expectations and the consumption of gasoline has increased in like proportion. A comparison of the price ratio between gasoline and the automobile of 10 years ago with the ratio of to-day shows that the automobile has advanced very little, but that gasoline has advanced from three to four times the former price. The low cost of fuel is one reason that has enabled us to carry on large automobile production in this country. What will happen if the cost of this fuel goes beyond the reach of the buying public? The large production of automobiles which we have been enjoying will be cut down materially and conditions will parallel those of Europe. What good will it do to build cars at a low price, if the cost of maintenance is beyond the reach of the middle classes? The conservation of fuel is a foundation for large production. Unless the car builder works to that end, or the petroleum producers find a substitute fuel, the automotive industry will suffer.

In addition to using less pounds of fuel per horsepower-hour, the small high-speed engine has important features. One is that of light weight, which is a great step toward economy; less power is required to propel the car, less tractive effort is needed and the strain on the tires is not so severe. The flexibility of a high-speed four-cylinder engine approximates that of the "multi-cylinder" engine. The buying public is more familiar with the general construction of the four-cylinder engine than with that of the other types. The cost of repairs also is an important item; the fewer the number of parts that require overhaul, the better the owner should be pleased.

Engine Specifications

Now that the reasons for such an engine and its importance have been stated, we will outline some specifications. The engine should be of the four-cylinder type. As has been said, a high-speed engine should have as few moving parts as is possible; the having of fewer moving parts tends to make it more reliable. It also makes a short engine, which allows more body room and decreases the chances for torsional vibration in the crankshaft. The engine should have a displacement of about 165 cu. in. for a car with a wheelbase of approximately 118 in., a bore of say 3¼ in. and a stroke of 5 in. The valves should be located in the head, as this gives a more ideal combustion-chamber, and should be at least 1⅝ in. in the clear with a lift of at least ⅜ in.

The camshaft should be overhead and run in a bath of oil, but it should be arranged so that no large quantity of oil can get to the valves and cause trouble; otherwise the oil will be drawn in around the inlet-valve stem and have a tendency to foul the cylinders and cause a smoky engine at low throttle-positions. The drive of an overhead camshaft has been more or less a problem. A silent chain is out of the question and the ordinary bevel gear is too noisy, but it seems that the application of a helical bevel gear would solve this problem. The drive from the crankshaft should be taken through a pair of spur gears, to prevent the tendency of crowding because of any lateral motion of the crankshaft. From the spur gear, the drive should be through bevel gears and a vertical shaft to the camshaft, a suitable coupling being devised between the cylinder and the head to enable the head to be removed, the carbon deposit cleaned out and the valves ground, without disturbing the timing of the engine. We recommend an overhead camshaft because we believe that lifter-rods and rocker-arms are not practical for high-speed work. The inertia forces of the rocker-arms and lifter-rods run too high to be overcome by any reasonable amount of spring-pressure; it is difficult also to lubricate them properly. In addition, it is almost impossible to maintain proper adjustment, the engine becomes noisy and must be tampered with continually.

The crankshaft is of course a fundamentally important part of this engine. It should be counterbalanced. The crankpins and main bearings ought to be not less than 2⅛ in. in diameter, and there should be at least three main bearings. It is well to drill the crankpins hollow, reducing their weight and at the same time keeping the material at a point where it will do the most work.

The piston, wristpin and connecting-rod must be very light. The length of the connecting-rod should not be over twice the stroke. In the case of the engine described this would be 10 in. The reason for making these parts light is to reduce the load on the bearings as much as possible and to eliminate to a great extent the vibration caused by the differential speed of each pair of pistons as they pass the top and the bottom centers. This type of vibration becomes clearly evident at high engine speeds and cannot, of course, be overcome entirely in a four-cylinder engine.

The cylinders should be cast in block and surrounded with plenty of water, especially around the valves. At high speeds the heat becomes very great at these points; lack of water means distortion of the valve seats, which would cause a drop in power if the engine were run at wide-open throttle. When there is no room for a spark-plug in the top center of the combustion-chamber, we recommend the use of two spark-plugs, one in each side of the combustion-chamber; this gives excellent water circulation around the spark-plugs. We have found that,

[1]M. S. A. E.—President, Frontenac Motor Co., Indianapolis.
[2]Chief Engineer, Frontenac Motor Co., Indianapolis.

with engines having spark-plugs in each side, by cutting out the spark-plugs on one side there was a considerable drop in horsepower. Of course, this is more noticeable in engines of relatively large bore than with those having a small bore; but it has considerable effect on both, especially with the fuel mixtures we have to burn at present.

The lubrication of the engine should be a pressure-feed in all cases, and oil should be pumped through the engine in as large a quantity as possible. Provision should be made also for carrying a large quantity of oil in the engine; this will give the oil a chance to cool off before being pumped through the engine again. A compartment should be provided in the bottom of the crankcase where the oil will not be agitated, so that the carbon deposits and dirt can settle out. Clean oil adds materially to the life of the engine. We believe that before long engines will be fitted with small centrifugal oil-cleaners that can be removed, cleaned out and replaced without much trouble.

Carburetion on an engine of this type is another problem. To obtain efficiency at high speed the manifold must be large; it should be 1¾ to 1⅞ in. for an engine of the size which we are discussing. A manifold of this size will probably give trouble by loading-up at low engine speeds, and this would interfere with securing the good performance that people look for in an automobile. However, this trouble might be overcome by the use of a double manifold and carbureter, one large and one small, the latter to be used in taking care of speeds up to 25 m.p.h. and the former coming into play from there on. As most of the running of a car is done between 15 and 25 m.p.h. the small carbureter could be run practically wide-open all the time. This undoubtedly would give high economy and, owing to the high velocity of the gases, there would not be a tendency to load-up.

The inlet manifold should be carefully worked out to assure even distribution of the gases. With a large manifold and a large volume of gas at a high velocity there is a tendency for the gas to bank-up toward the two end cylinders. If this occurs, the two middle cylinders starve and immediately the exhaust valves of cylinders Nos. 2 and 3 become overheated and burn.

A high-speed engine should be equipped with a four-speed transmission driving direct on the third and geared-up on the fourth speed. On smooth level roads the fourth speed could be used, giving good touring speeds at moderate engine speeds and lengthening the life of the engine. The automobile should be built to a higher standard for the use of the high-speed engine. To be successful the manufacturer should work to a greater degree of precision and, as the working parts of the engine are all light and stressed fairly highly, this necessitates the use of high-grade materials properly heat-treated. Several attempts have been made in this country to produce high-speed engines, but for some reason they have not been very successful. However, there are a few small cars of this type that seem to give very good satisfaction, and we look for more developments along this line in the near future.

The Engine Described

Fig. 1 shows the high-speed racing engine designed by us, which won the 500-mile race on the Indianapolis Speedway in 1920. It is necessary in this type of high-speed engine to cut down the friction as much as possible. We attempted to do this in several ways. One is that the water-pump and the ignition system, which consists of a generator and a distributor and forms a unit with the water-pump, are placed in front of the engine and driven by what can be called the idler gears. The last named form part of the set of spur gears which drive the camshafts. Thus we eliminated several gears which usually run off to one side or the other to drive the water-pump and the ignition system. This makes a very clean, narrow and accessible engine.

This engine has two overhead camshafts in separate housings. The valve-actuating mechanism consists of a finger having a curved surface forming the section of a roller upon which the cam rides. This finger is to take the side-thrust. Between it and the valve-stem proper there is a straight piece of steel that might be called a tappet. This is the only means of adjustment and is ground to give the proper clearance. This makes a very light valve mechanism and needs very infrequent adjustment.

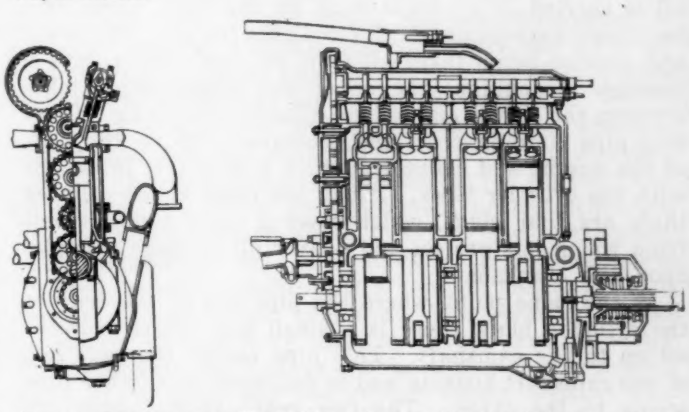


Fig. 1—Section of a High-Speed Racing Engine Having a Small Piston Displacement

As to the cooling of the pistons, it is not practical to use the method of heat dissipation through the wall of the piston to the cylinder wall and thence to the water in the jacket, because the wall area necessary in this case to conduct the heat from the pistons is so great as to make the pistons too heavy to travel at the required rate of speed. We have found that it is possible to air-cool these pistons, obviating the large wall area mentioned. This accounts for the unusually large breathers on the side of the engine, one in front and the other in the rear. The front one has a funnel-shaped top covered with a 16-mesh screen which prevents large particles from getting into the crankcase. The air goes in through this front breather-tube, through the crankcase and out through the rear breather, which has an inverted tube facing downward in a compartment separated from the crankcase proper, with a port entering the chamber at the top and also one at the bottom. The breather-tube in this chamber is sealed at the top and has a series of staggered holes down its side. It was designed to take as much air as possible from the crankcase and condense the oil vapor at the same time. The theory is that the air, due to the rotation of the crankshaft, passes in at the upper port and down and around the breather-tube. The oil vapor, settling on the wall surfaces, runs down and out through the lower port and back into the crankcase, while the air escapes through the holes in the wall of the tube and so on to the outside of the car. Of course, there is always more or less oil mixed with the air, and this is lost.

Two separate oiling systems are used on this engine; one mechanical and the other manual. The manual system is for emergencies; it is never used unless some-

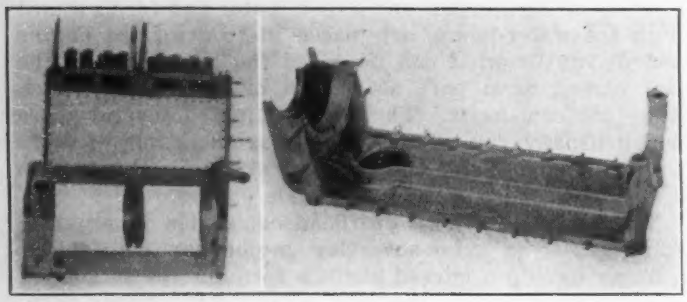


FIG. 2—THE CYLINDER BLOCK AND THE LOWER HALF OF THE CRANKCASE WITHOUT THE SIDE PLATES AT THE LEFT AND AT THE RIGHT THE LOWER CRANKCASE WHICH CAN BE REMOVED WITHOUT DISTURBING THE CRANKSHAFT

thing gets out of order in the mechanical system. Both systems are what is known as the dry-sump type. The oil is carried in an 8-gal. tank on the car. There is a two-stage gear-pump which circulates the oil. The lower and smaller pump takes oil from the tank and pumps it through the engine; the upper and larger pump takes oil from the engine and pumps it back to the tank. There is a pipe running from the pressure-pump up the back of the engine and connecting with a pipe cast integrally with the cylinder block. Along the edge of the cylinder there are four plugs, which cover a small compartment from which jets project and deliver oil to rings mounted upon the crankshaft.

At the same point where the pipe enters the rear of the cylinder block there is a small pipe which conveys oil up to the camshaft. This pipe enters the rear end of one camshaft housing and is delivered by another pipe across to the other. The two rear camshaft-bearings each have a groove completely around their circumference and, by this groove and through a hole drilled in the camshaft, the oil is forced along the inside of the camshaft, which is drilled hollow. At the heel of each cam there is a 1/16-in. drilled hole, which supplies oil to each cam mechanism. The oil which escapes from the camshaft, after doing its work, is conveyed along the bottom of the housing to the front of the engine where there is a channel beneath the ball bearing which allows it to run out and down over the timing-gears. The oil that does not escape through the small holes in the heel of each cam passes out through the front of each camshaft and also down and over the timing gears. After the oil goes down through the timing-gear case it runs into the crankcase and along the bottom to a cone-shaped strainer located in the bottom of the crankcase. Through this strainer it is delivered to a compartment which forms a reservoir to allow dirt and carbon to settle out before being taken up by the scavenger pump. The rib along the bottom of the crankcase is not put there for strength, but to form a baffle-plate to prevent the oil from surging about in the crankcase and also to convey it to the scavenger pump.

On the opposite side of the cylinder from the pressure oiling system there is another pipe cast integrally with the cylinder and having two jets, one at either end and opposite the center cheeks of the crankshaft. The oil is taken from the tank by the hand pump at the outward stroke, delivered to these two jets at the inward stroke and projected against the center crankshaft cheeks. The hole drilled in the cheek picks up a quantity of oil every time it comes opposite the jet. This same pump delivers oil to the camshafts by way of the pipe leading from the back end of the camshaft housing to the pressure gage on the instrument board. The oil is pumped out of the crankcase and back to the reservoir tank by another hand pump.

The spark-plugs in this engine were made especially for the job. We used one spark-plug per cylinder, located in the center between the four valves, an ideal position. This necessitated an extra-long threaded portion, to get down into the combustion-chamber and still permit water to circulate around the valves. If we had tried to use the standard type of spark-plug, the opening needed would have been so large as to take all the water space.

The adoption of two dial thermometers was an important matter as they give accurate account of what goes on in the engine. One of these which is for water is located in the outlet water manifold. The other is for oil and is located in the lowest part of the crankcase. The oil thermometer is very valuable to the mechanician; the moment a part becomes overheated, from either lack of oil or insufficient clearance, the temperature of the oil rises and is indicated upon the dial of the thermometer. In such case the driver should drive immediately to the pits and inspect the engine for the trouble. On certain occasions when connecting-rods become heated rapidly and the mechanician was either inattentive or had not sufficient time to notify the driver, the connecting-rods have left the engine and been lost to view.

At the left of Fig. 2 the cylinder block and lower half of the crankcase without the side-plates are shown. The valves are in place and also the studs which carry the camshafts and their housing. This cylinder construction should be of interest as it is more or less of a departure from regular practice, inasmuch as the crankshaft is supported by the cylinder itself rather than the cylinder being supported by the crankcase. The crankcase in this case acts merely as an oil retainer. This has proved to be a very light, rigid and satisfactory type of construction. Both sides and the rear of the cylinder block are covered with a No. 16 gage aluminum plate, fastened on with No. 10-24 fillister-head cap-screws. The openings which these aluminum plates cover form very large core-prints, which has a tendency toward securing accurate castings. Castings which we have sectioned have shown that the walls, which run from 1/8 to 5/32 in. in thickness, did not vary. The cylinder block as shown weighs 125 lb. The illustration shows the two steel tubes which support the engine in the frame. By removing the plates on the side of the crankcase, the connecting-rod and piston can be taken out of the engine without disturbing the crankshaft.

The lower crankcase at the right of Fig. 2 can be removed without disturbing the crankshaft, as the center bearing is separate and forms a supporting member. The baffle-plate or rib, already mentioned, can be seen;

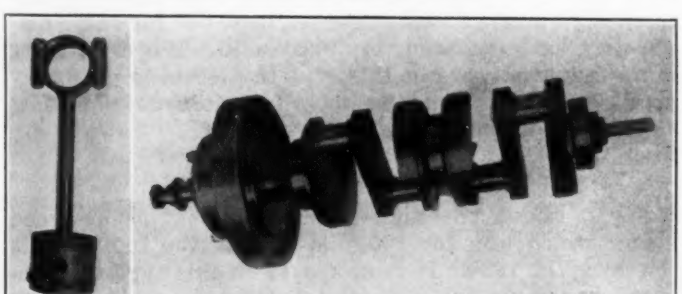


FIG. 3—THE CONNECTING-ROD AND PISTON AT THE LEFT AND THE CRANKSHAFT, FLYWHEEL AND CLUTCH AT THE RIGHT

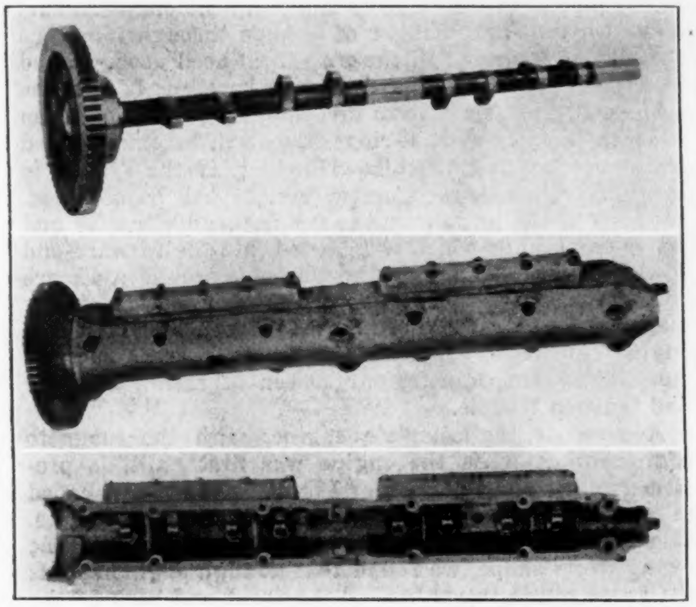


Fig. 4—One of the Camshafts at the Top with the Complete Cam Housing Underneath and an Interior View of the Housing with the Bronze Caps Forming Camshaft Bearing at the Bottom

also the oil-pump and the spiral gear which drives the oil-pump at one-quarter engine speed. This gives the oil-pump a capacity of 1 gal. per min. We have kept the speed of all parts as low as possible to reduce friction losses in the engine.

The view at the left of Fig. 3 shows the connecting-rod and piston. The piston is 2½ in. long, 3⅛ in. in diameter and has two cast-iron rings, ⅛ in. square. The connecting-rod is made of chromium vanadium steel containing 0.35 per cent of carbon. The bearing is bronze, babbitt-lined. The connecting-rod has two bolts to hold the bearing cap; the pillar of the rod is drilled hollow and has a wall thickness of 1/16 in. The weight of the piston, with the wristpin and connecting-rod as shown, is 2 lb. 14 oz. The rod is 9 in. between centers. This is short for the amount of stroke, as in ordinary passenger-car practice a stroke such as we have here would call for not less than a 12-in. connecting-rod, but we find that we gain higher mean effective pressures with a short connecting-rod and also decrease the weight of the rod considerably. This connecting-rod has proved very satisfactory and never given trouble. The pistons are of aluminum and rough-machined, heated to about 700 deg. fahr. and then finished. This removes all internal stresses and they hold their shape under the high temperatures they attain in the engine.

The right section of Fig. 3 shows the crankshaft, flywheel and clutch. The crankshaft is very heavy, weighing 165 lb., and is counterbalanced. It might be advantageous to drill this shaft hollow and lighten it considerably, especially the crankpins. This would reduce also the weight of the counterbalances and thereby decrease the total weight of the shaft without lessening its strength much. The crankshaft is mounted on three ball bearings. It is made in two pieces and assembled in the center. It is locked rigidly by three hardened keys and can be taken apart and reassembled without disturbing its alignment. If we were building another crankshaft of this type we would make the center cheeks more nearly square and drill the center from end-to-end hollow, making it rigid and lighter at the same time. At the front end of the crankshaft the gear which transmits the power required to drive the camshafts is shown.

The upper view in Fig. 4 shows one of the camshafts. There are two plain bearings and one ball bearing in front which supports the timing-gear. Attention should be called to the heavy rim on the camshaft gear; this is for a flywheel effect. The camshafts run at sufficiently high speeds to store up considerable energy, which assists in opening the valves against the high spring-pressures we use. These are in the neighborhood of 125 lb. The cam has a lift of 7/16 in. The camshaft, drilled hollow as mentioned, has a wall thickness of ⅛ in.

The complete cam housing is illustrated in the middle portion of Fig. 4, while the bottom view shows the interior of this housing with the bronze caps forming the camshaft bearing and the fingers, which have been mentioned before, in place with their housing. By removing small screws the fingers can be removed in units of four, inspected, repaired if necessary and replaced in a very short time. The channel, which has been mentioned, is shown underneath the ball bearing, where the oil is allowed to run out at the front of the housing. The fingers do not have rollers but simply curved surfaces.

Fig. 5 presents two views of the timing-gear housing. That at the right is looking at the front of the housing, which is fastened to the forward end of the engine. The bottom hole is where the crankshaft projects through. The machined surface above it is for the water-pump and generator bracket. The shaft in the middle drives the water-pump. Above it is a toothed flange which is part of the generator coupling. The coupling at the generator has one tooth less. A rubber member which fits in between the flanges enables a micrometer adjustment to be made and the rubber center member provides a flexible joint that absorbs much of the shock present in timing-gears. The other side of the timing-gear housing is shown at the left of this illustration with the timing gears in place. These gears are made of chromium-vanadium 0.50 per cent carbon steel, heat-treated. The teeth are 12-pitch. The webs are drilled

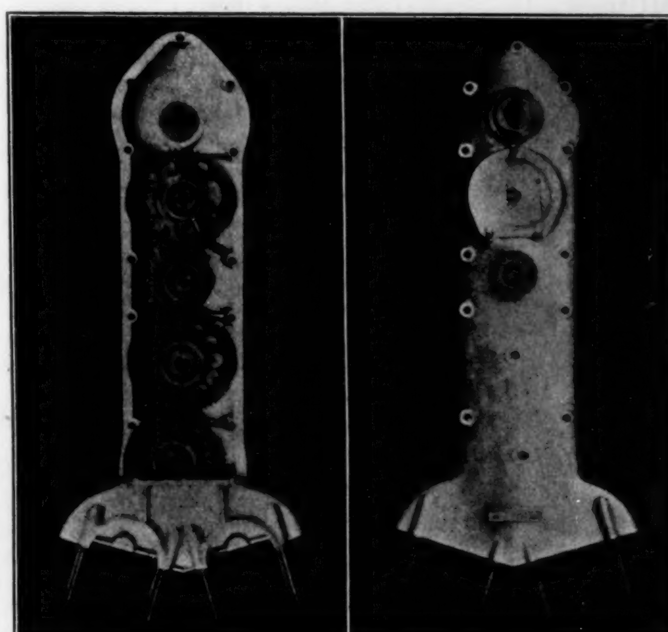


Fig. 5—Two Views of the Timing-Gear Housing

The View of the Left Shows the One Side of the Housing with the Gears in Place, While the View at the Right Is Looking Toward the Front of the Housing Which Is Fastened to the Forward End of the Engine.

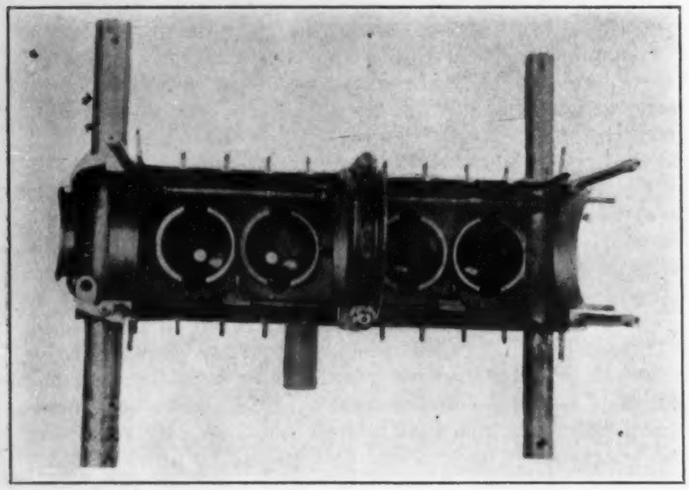


FIG. 6—LOOKING INTO THE CYLINDERS FROM THE BOTTOM

hollow for lightness and mounted on a single-row ball bearing. The ball bearings are held in the gear by simply turning over the edge of the gear against the chamfer on the outer race of the ball bearing. The lower gear drives the water-pump. The one directly above and meshing with this gear drives the generator. This gear is really smaller than it should be, as the engine was originally designed to take a magneto that had to run at crankshaft speed, which is much faster than is really necessary to run a low-voltage generator. It was determined after test to use the battery system of ignition in place of a magneto on account of the high engine speed, which is from 3400 to 3600 r.p.m.

Fig. 6 is the view seen when looking into the cylinders from the bottom. It shows clearly the oil-pipes already spoken of, the valves in place in the head of the cylinder and also the steel supporting tubes.

Fig. 7 is a close-up view of the oil-jet which supplies the oil to the oil-ring on the crankshaft. The oil leaving this jet is directed against the side of the oil-ring and carried by centrifugal force into a deep groove inside the ring and a hole connecting this groove with the connecting-rod bearing. The centrifugal force in this ring of oil exerts a pressure of about 40 lb. per sq. in. at the connecting-rod bearing. This system of oiling has its advantages and disadvantages, a very good feature being that the oil can be carried under high pressures to the connecting-rod without excessive pressures

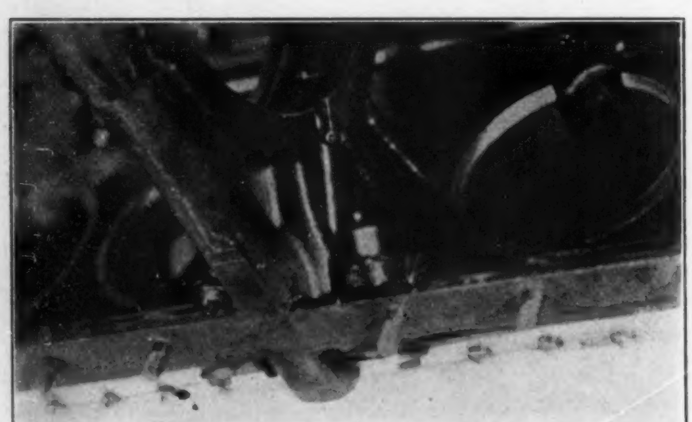


FIG. 7—THE OIL JET WHICH SUPPLIES LUBRICANT TO THE OIL RING ON THE CRANKSHAFT

in the pipe lines which go to and from the engine. This does away with the danger of leakage through joints, as the pressure carried in the pipe lines need never exceed 5 lb. per sq. in. One disadvantage, however, is that the system is very sensitive to dirt and, if care is not taken to clean the jets and oil-rings, they will become clogged and cause bearing trouble. However, if the system is carefully watched, satisfactory results will be obtained.

Fig. 8 at the left shows the generator, distributor and water-pump unit, which is fastened into the forward end of the engine. This might have been executed in a more compact manner had it not been a replacement for magneto equipment. For the high speed at which this engine ran, battery ignition proved to be very successful. At no time during our season of racing have we had ignition trouble.

A view of the complete engine, with the magneto equipment as when the engine was first built, is presented in the right portion of Fig. 8. Attention is called to some experience we had with the distribution of gases. The manifold shown has an inside diameter of 2 in.; owing to its shape, we found that at high engine speeds the gases would travel toward the front and back of the engine; before cylinders Nos. 2 and 3 could take in a charge, it was necessary for the gas to bank-up in the end of the manifold and form its own passage to cylinders Nos. 2 and 3. This, of course, had a tendency to starve the two middle cylinders. A mixture suitable for the end cylinders would cause overheating of the two middle cylinders, resulting in the overheating of the valves. Not having time to experiment with manifolds, we substituted a small baffle-plate in the outer wall of the manifold, which served to deflect the gases toward the center. By a small amount of experimenting, which was merely cutting off the end of this baffle-plate and watching the exhaust, we were able to determine the proper setting. Unfortunately, this held good only at one certain speed; dropping below or going above that speed tended to reverse conditions and again cause trouble; but, as in our case the engine ran practically at a constant speed, we were able to use the manifold with fairly good results. We also tried the use of two carbureters with separate manifolds, but this was not at all satisfactory. The velocity of the gases was so great that when the valves closed there was a plus pressure against the back of the valves which resulted in a blow-back through the carbureter. To correct this we tried a by-pass from one manifold to another to allow the plus pressure to be conveyed to the other manifold, but this did not prove successful.

The valves in this engine have a diameter of 1 7/16 in. in the clear, and a lift of 7/16 in. The area of opening for one valve is 1.70 sq. in.; the total valve area is 6.81 sq. in. The engine, on the dynamometer, delivered 86 hp. at 3200 r.p.m. This is not as high as has been reported from tests of eight-cylinder engines of the same piston displacement. On a test under a wide-open throttle this engine, running at 3200 r.p.m., delivered an average of 78 hp. for 1 hr. The result might have been better had the air in the test-room not been contaminated with exhaust gases, causing a considerable drop in the horsepower. We found that when starting up with a clear room the engine would pull very well; as the room became filled with burnt gases the beam of the dynamometer scale would begin to drop. During this 1-hr. run the engine had a gasoline consumption of 0.625 lb. per hp-hr. This same engine ran 500 miles on the Indianapolis speedway at an average speed of 88.7 m.p.h., with an

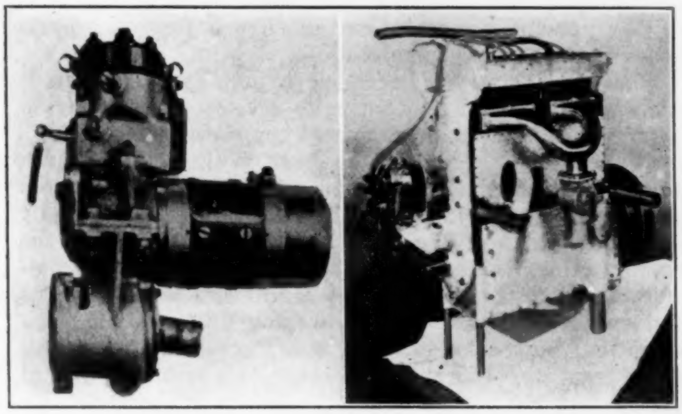


FIG. 8—THE GENERATOR, DISTRIBUTOR AND WATER-PUMP UNIT WHICH IS FASTENED INTO THE FORWARD END OF THE ENGINE AT THE LEFT AND AT THE RIGHT A VIEW OF THE COMPLETE ENGINE AS IT WAS FIRST BUILT WITH THE MAGNETO EQUIPMENT

average of 10 miles per gal. of gasoline for the whole race.

The water manifold, with a small pipe which leads to the thermometer, and the breather pipes, front and rear, are shown. It can also be seen how the covers come completely off the side of the crankcase. This opens up the whole side of the engine, making it very accessible besides being very light in weight. The whole engine, with exhaust manifold complete, weighs 410 lb.; a large part of this weight is, of course, in the crankshaft, which weighs 165 lb.

THE DISCUSSION

A MEMBER:—At what engine speed was maximum horsepower obtained?

C. W. VAN RANST:—At maximum horsepower on the block the engine speed was 3200 r.p.m. On the track we continued up to 3500 and 3600 r.p.m.

MAX H. THOMS:—What is the axle ratio?

MR. VAN RANST:—It is 3 to 1.

MR. THOMS:—What sizes of tire were used?

MR. VAN RANST:—Three cars, the winner among them, used 32 x 4 in. front and 32 x 4½ in. rear tires. The others used 32 x 4½ in. front and 33 x 5 in. rear tires.

MR. THOMS:—What is the material in the flywheel and the diameter of the flywheel?

MR. VAN RANST:—The material is plain carbon steel; the flywheel diameter is 13 in.

A MEMBER:—Please describe the breather system, from the radiator to the crankcase.

MR. VAN RANST:—The air comes through the radiator and there is enough draft to force it through the crankcase. The ideal condition would be to take it from outside, but the air comes through the radiator so fast that it does not heat up to a high degree and so it makes no difference.

A MEMBER:—Do you have trouble with accumulations of dirt in the oil?

MR. VAN RANST:—The greatest trouble in taking air into the crankcase is with dirt; it is serious and a thing we would like to get away from. We have to give the crankcase air or it will become too hot. There are means, I suppose, whereby we could get a less amount of dirt. I think it important to give all the air possible. That is one reason I mentioned that the crankcase should be fitted with a compartment where the dirt and carbon can filter out of the oil and not be carried through the engine.

GEORGE A. WEIDELY:—You obtained 10 miles per gal. of gasoline; how many miles did you obtain per gallon of oil?

MR. VAN RANST:—We prefer not to state that figure because this type of engine is not economical with oil. Due to the arrangement of the camshaft and because the valve mechanism is open, much oil is lost. The racing-car engine, unfortunately, seems to slobber a lot of oil, anyway; especially in this type, where the breather is large and the cam housing is overhead. The oil consumption was very high.

CHESTER S. RICKER:—What kind of oil was used?

MR. VAN RANST:—Straight castor oil. We tried mineral oil but found that the carbon deposit was too great and caused us to burn out three connecting-rods. After we used castor oil we never burned out a rod. The other oil would become foul and the jets would clog; immediately a rod would burn. With castor oil there was very little carbon and the oil had greater body. The temperature of the oil runs anywhere from 220 to 250 deg. fahr.

A MEMBER:—Do the fingers on the cams take all the thrust of the cams?

MR. VAN RANST:—Yes.

MR. THOMS:—What tappet clearances are there on the exhaust and inlet valves?

MR. VAN RANST:—The exhaust has 0.030 in. and the inlet 0.025 in. clearance.

A. L. NELSON:—In regard to experiments with fuels and compression ratios, what was done?

MR. VAN RANST:—We carried on a few experiments. Recently we tried a "dope" which Mr. Kettering prepared to retard the speed of combustion and prevent detonation. We found that in this type of engine it proved to be of no advantage. We experimented with compressions up to 135 lb., varying the percentage of dope to gasoline from 3 to 3½ per cent; but we lost power as compared to regular practice. The compression ratio that we found to be best was 5 to 1, which gave about 105 lb. per sq. in. gage compression.

A MEMBER:—What is the comparison of an engine of the type described with the standard type, as far as quietness is concerned?

MR. VAN RANST:—At ordinary traveling speed there is no reason it should not be as quiet as the average engine of to-day. I believe it would be more quiet than engines with the rocker-arm and lifter-rod valve actuation used in the cheaper classes of car. Also, at higher speeds I believe it would be more quiet; but there would be less tendency for the valves to flutter, due to the elimination of rocker-arms and lifter-rods, although at higher speeds there is a considerable hum anyway. I believe the noise would not be detrimental. I know of no engine that I would call quiet when running at high speed.

DANIEL C. TEETOR:—Is there anything special in regard to the design of the piston-rings?

MR. VAN RANST:—No; they are of cast iron, cast separately and machined to be ⅛ in. wide and ⅛ in. deep; two rings are used, with just an ordinary 60-deg. slot.

A MEMBER:—How much clearance is there beneath the rings?

MR. VAN RANST:—The clearance is 0.010 in. overall; that is, 0.005 in. on each side.

A MEMBER:—What material is used for the timing-gears?

MR. VAN RANST:—They are of chromium vanadium steel containing 0.50 per cent of carbon and heat-treated.

A MEMBER:—How are the timing-gears kept quiet?

MR. VAN RANST:—We do not attempt to keep them quiet; they hum considerably when running. They could not be made quiet, because the webs are drilled, this tending to make them noisy.

A MEMBER:—How could that be corrected in a commercial car?

MR. VAN RANST:—I would recommend the use of helical bevel gears, having them drive a vertical shaft to the overhead camshaft.

ARTHUR HOLMES:—In what manner are the wristpins lubricated?

MR. VAN RANST:—By splash. Two small holes are drilled in the top of the wristpin boss and there are grooves the full length of the bearing inside. The oil coming from the connecting-rods is thrown upward into the cylinder and is picked up by these holes. Oil is also picked up from the cylinder wall by the wristpin hole.

LON R. SMITH:—What is the size of the crankshaft?

MR. VAN RANST:—The crankpin is 2⅛ in. in diameter. The main bearings are ball bearings 2¼ in. long and are very large.

A MEMBER:—Do you use shims in the connecting-rods?

MR. VAN RANST:—There are no shims and no grooves. We could not use shims, as this would cause a slot the entire length of the bearing which would allow the oil to pass through, because it is under such high pressure, and would probably cause a smoky engine. We have to keep the bearing as tight as possible, aside from the necessary clearance.

A MEMBER:—What is the pressure of the oil at the connecting-rods?

MR. VAN RANST:—It is calculated to be 40 lb. per sq. in.

A MEMBER:—Did you have any difficulty with the babbitt separating from the bronze bearings?

MR. VAN RANST:—There were only two or three instances that I know of where the babbitt became loosened from the bronze.

MR. WEIDELY:—Those who have interested themselves in racing or other contests are familiar with the fact that many such events have been won by road ability rather than because of engine output; on the other hand, faults of the present-day motor-car often are found in parts other than the powerplants.

The limiting of displacement in our more important races has supplied an incentive to develop engines having abnormal torque at an abnormal compression and a still more abnormal speed, which has resulted in research along the line of engine improvement to the exclusion and detriment of improvement in other almost equally important parts of the car. It is doubtful whether the results gained in racing events help to improve the commercial article as much as they might and would if rules and conditions were added covering fuel and oil consumption, power losses, tire wear, acceleration, ability and durability of brakes and other things looked for in the modern car.

In view of the fact that probably all present-day cars, racing or otherwise, show a power loss at the wheels of over 20 per cent exclusive of slip, there seems to be food for thought in a direction other than toward the engine. It is true that these matters might detract from the sporting side of a contest, but the results from such events would, no doubt, pay in a big way if these matters were considered. I have just learned that the part of the rules covering the bench and dynamometer tests of all cars entered in the Grand Prix Race, in France, has been dropped. This is really a misfortune for the industry as a whole, as otherwise no doubt much useful information could have been gained.

MR. RICKER:—There was recently a very interesting contest in France in which the fuel consumption was the criterion rather than the engine displacement. The question of a bench test for the French Grand Prix Race was largely, I understand, a matter of not desiring to put an engine to that test before it had to go into the race. A race is a question of a complete chassis rather than one of the engine alone. On a bench test the engine might break down or a good engine that did not fulfill the exact conditions might be eliminated; yet the engine and the chassis in which it was installed might make an ensemble that would win the race. Some of the suggestions that Mr. Weidely makes might well be considered by automotive engineers and especially by the automobile contest organizations of this country.

GRAPHITE LUBRICANTS

IT is obvious that to try to use graphite as a lubricant instead of oil would be useless, as solid friction is always greater than liquid friction. The oil used must be able to keep the metallic surfaces apart, either by its oiliness, its power of creeping with an unbroken film over the metal, which necessitates a low surface tension, or by its viscosity, whereby it is carried along by the rotating portions, and wedged in between them and the fixed portions. To use an oil of a viscosity more than sufficient to do this is wasteful, as energy is lost in shearing oil. Liquid lubricants, however, are greatly influenced by a rise of temperature, and a decrease in the viscosity of about 3 per cent per degree centigrade is quite a usual value for thick oils between 60 and 90 deg. cent. At cylinder temperatures all oils have very much the same viscosity. Under such severe conditions liquid oil films are apt to break, so the presence of a solid lubricant like graphite, which is almost entirely unaffected by such temperatures, is highly desirable. Graphite, then, may be considered as a lubricant of special value for cylinders and valves of internal-combustion engines. It is also of value for use on bearings, especially when subjected to heavy pressure, in which case the oil film may fail. A graphite film in a bearing, besides reducing the solid friction of metal to metal, provides a skin which is renewed from the oil, this skin being worn away instead of the metal. After graphite has been in use in an engine for some time the amount in the oil, always a very small quantity, can be further reduced, for once the graphite surface is formed a very small quantity suffices to maintain it. It is difficult to explain why the use of graphite reduces the consumption of lubricating oil, but it undoubtedly does so. The film deposited is too thin sensibly to alter the clearances. The explanation which appears the most probable is that by reducing the friction and the eddy currents in the oil due to surface irregularities, the temperature of the oil film is, on an average, reduced, and its viscosity being on that account greater, its rate of flow is diminished. It is also possible that, on the cylinder walls, where oil probably vaporizes with the fuel, a certain residue of graphite remains, and in this case the clearances between piston rings and cylinder walls may be slightly reduced. Apart, however, from any explanation of its action, the saving is an established fact, and in certain cases it appears that power also is saved.—W. R. G. Atkins in *Automobile Engineer*.

Recent Development of Artillery Automotive Material

By CAPT. J. B. HANEY[1], U. S. A.

CHICAGO TRUCK AND TRACTOR MEETING PAPER *Illustrated with* PHOTOGRAPHS

LAST year at the Chicago Truck and Tractor Meeting George W. Dunham read a paper entitled Artillery Motorization as Related to Caterpillar Traction[2], in which the problem of artillery motorization and the achievements in that line up to the end of 1919 were presented in a clear and convincing manner. In this paper I will undertake to describe briefly the progress of the work of artillery motorization in the past year. Mr. Dunham referred to the Westervelt Board, appointed by the War Department to make a study of the armament, calibre and types of material, kinds and proportion of ammunition, and methods of transport of the artillery to be assigned to a field army. This Board made a very complete report based on the experiences of the Allied Armies during the war, and its recommendations will be the basis of armament development for some time to come. Without going into detail it will be sufficient to note that the development of the following track-laying material is directly recommended by the report of this Board:

FIG. 1—EXPERIMENTAL TRACTOR HAND CART WITH A LOAD OF 310 LB. BEING PULLED OVER SOFT WET GROUND BY ONE MAN

- Tractor hand-cart
- Reconnaissance tractor
- Division artillery tractor
- Corps artillery tractor
- Army artillery tractor
- Heavy or 15-ton artillery tractor
- Tractor caissons of 1½ and 3 tons capacity
- Trailer caissons of 1½ and 3 tons capacity
- Self-propelled mounts for the division, corps and army gun and howitzer.

The Board also recommended investigation of the use of wheeled trailers on which the track-laying material could be loaded and towed over good roads by trucks, and of the possibility of incorporating trailer wheels in the track-laying vehicles themselves.

The various types of material constructed in the past year will be taken up in the order given. The first of these is the tractor hand-cart recommended by the Westervelt Board in approximately the following terms:

> A cart with caterpillar tracks to be pushed or drawn by one or two men, to be used as an ammunition carrier in stabilized warfare, or for carrying other miscellaneous supplies, which due to local conditions would otherwise have to be carried by men on foot.

A suitable mechanism for applying power direct to the track, which would enable the cart to be worked over steep grades or terrain over which two men could not draw or push it was also to be provided. Specifications were drawn up for this tractor hand-cart and bids on designs asked for, but no bids being obtained the design work was assigned to the engineering offices of the Tank, Tractor and Trailer Division of the Ordnance Department. In the absence of any data on track-laying vehicles of this type an experimental model, shown in Fig. 1, was constructed rather for the information of the designer than with the idea of producing a vehicle for test by the Ordnance Department or the service. It is 36 in. long and 24 in. wide overall. The load capacity is 200 lb. The body is watertight and of sufficient displacement to float the cart with a full load, as can be seen by referring to Fig. 2. The estimated weight of a cart of this type was 125 lb., but the weight of this preliminary model is somewhat greater. The design shown here has a pulley and ratchet mechanism, by which power can be applied to the tracks in accordance with the specifications. This model proved successful in the various tests and demonstrations to which was subjected, but it has been decided that the limited service a cart of this type can give will not justify its development at this time.

The ¼-ton or reconnaissance tractor shown in Fig. 3 is intended to fill the gap in motorized artillery left by the horse of the individual mounted man, as it is not practicable to combine horse and motor transport in the

FIG. 2—EXPERIMENTAL TRACTOR HAND CART FLOATING WITH A LOAD OF 360 LB.

[1] Ordnance Department, Washington.
[2] See THE JOURNAL, March, 1920, p. 161.

FIG. 3—EXPERIMENTAL RECONNAISANCE TRACTOR

same unit. The motorcycle has been tried for the transport of officers, scouts, signal men, etc., but as it requires fairly good roads; its use is limited. The recommendations of the Westervelt Board were for a reconnaissance tractor weighing 1200 lb. with a load capacity of 500 lb. and a maximum speed of 15 m.p.h., but both types of vehicle produced have exceeded this weight limit considerably. As can be seen from Fig. 4, this tractor will operate in water of considerable depth. Its body has sufficient displacement to float the tractor with its load, while its weight is such that it can cross on improvised bridges, trenches or ditches too wide for it to cantilever. Power is furnished by a Militor motorcycle engine fitted with a Sirocco fan to supply air for cooling. The specified high speed is 15 m.p.h., but rates in excess of this have been maintained for short periods.

The striking feature of this tractor is the track invented by Lieut.-Col. A. M. Chase, who is now in charge of the Syracuse Engineering Office of the Tank, Tractor and Trailer Division of the Ordnance Department. This track has been used also on tractor carts designed by Colonel Chase. It will, it is thought, make possible the construction of small vehicles of the types just described without exceeding reasonable weight. This track consists of two fiber strips connected at intervals by arch-shaped metal pieces which bear on the rubber-tired wheels. Steps are being taken to subject this type of track to a test that will determine its durability.

A second model of the reconnaissance tractor is shown in Fig. 5. This has not yet been given a test or demonstration, so there are no data as to its performance. It has a water-cooled engine and a metal track. A similar model is being built, but with an air-cooled engine and a combined fiber and metal track. When the second model is completed, tests will be made to determine the ability of this type to fulfill the requirements of the Westervelt Board.

[3] See THE JOURNAL, October, 1920, p. 321.

FIG. 4—RECONNAISANCE TRACTOR WITH LOAD IN DEEP WATER

HEAVY TRACTORS

Next is the Division or $2\frac{1}{2}$-ton tractor. Its name indicates the ideal weight of the size of vehicle wanted but so far this has not been realized. The first Division tractors were built in 1918 but were finished too late to be of service during the war. Before putting them into service the Ordnance Department found it necessary to make rather extensive modifications to eliminate certain defects, so none of these tractors actually went into service until 1920. As now constructed the tractor weighs 7700 lb. It has speeds ranging from 5 to 9 m.p.h. at normal engine speed but a rate as high as 12 m.p.h. has been maintained for short periods. This tractor which is illustrated in Fig. 6 is still regarded as an experimental type but several organizations have been equipped with them with a view to obtaining more definite information as to the tactical requirements of high-speed tractors for Division Artillery materiel.

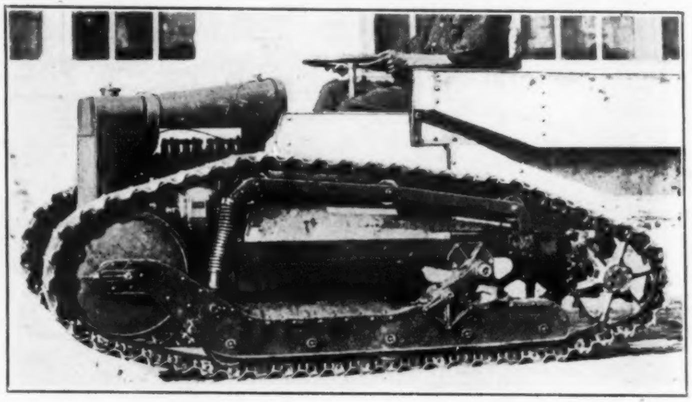


FIG. 5—ANOTHER TYPE OF EXPERIMENTAL RECONNAISANCE TRACTOR

A tractor or other track-laying vehicle intended for use in the theatre of operation of an army requires sufficient power available at the tracks to move it and its load over the terrain likely to be found there. It will be required to cross trenches, to climb into and out of shell holes, travel through mud-swamps and cross streams of considerable depth. This mobility is best secured by a very low track speed with the engine developing its maximum torque. On the other hand, the tractor must be capable of sustaining the same or greater speed than a truck train when operating on good roads, assumed as 12 m.p.h. In case of rapid concentration of troops or surprise attacks, when the troops are moved in trucks, the artillery must accompany them and be ready to go into action with the infantry; otherwise valuable time would be lost.

The Ordnance Department designed and built the Division Artillery tractor model of 1920 shown in Fig. 7 in which the defects of the earlier models were avoided and the requirements for higher speed were successfully met. This tractor was exhibited at the Summer Meeting of the Society at Ottawa Beach, Mich., in June, 1920, and a very complete description by the designers, G. R. Pennington and S. K. Wellman, was published in THE JOURNAL for October 1920,[3] under the title the New Army

Light Artillery Tractor. It has speeds ranging from 1 to 15 m.p.h. with the engine running at normal speed, and by speeding up the engine it has attained 18 m.p.h. Every effort has been made to build this tractor to operate with the least practicable noise, rubber-cored track rollers being used. It is waterproofed to operate successfully in water 4½ ft. deep at a speed of 7 m.p.h. While the track-supporting system operates satisfactorily, to offset the effects of loading the track, it has been found that it absorbs considerable power; experiments are under way in this connection. The formal test which the tractor is now undergoing will give sufficient data to determine whether the system mentioned will be retained.

Supply and Maintenance

With respect to supply and maintenance the ideal Artillery tractor would be one produced in quantity for commercial uses. Unfortunately, however, three factors on which the Army places considerable stress, speed, waterproofing and quiet operation, do not as yet enter decisively into the design of commercial tractors. If commercial tractors fulfilling all the requirements of the Army are not obtainable, the next best thing is to find one that with the fewest modifications will meet them approximately. We have not found such an one, but one is being developed that seems very promising. Its development belongs to the current year, however, and not to 1920.

Unless an emergency should arise in the near future, it is intended not to build any more 5 and 10-ton tractors of the type now in use, but to develop a new tractor of a size between those of the Division tractor described above and the 15-ton tractor now under construction by the Ordnance Department to carry out the recommenda-

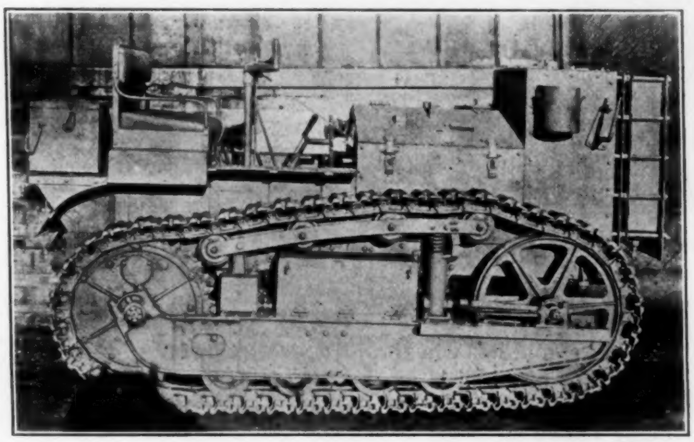


Fig. 6—Division Artillery Tractor

tions of the Westervelt Board, the latter tractor will be completed during the present year.

But little can be said in reference to tractor caissons. The types, both domestic and foreign, built during the war, were of too great weight to operate economically. So far nothing to replace them has been developed. Trailer caissons of ¾, 1½ and 3-ton capacity, the two last named recommended by the Westervelt Board, are under construction, but so far but one, a 1½ ton-trailer, shown in Fig. 8, in which the track mechanism of the model 1920 tractor is used, has been offered for test. The absence of the track-supporting mechanism so evident in the tractor should be noticed.

The track-laying trailer problem is a rather difficult

Fig. 7—Two and One-Half-Ton Division Artillery Tractor Designed by Ordnance Department Climbing

one. The question whether the body shall be supported at two points like a two-wheeled cart or at three or four points is unsettled. Sharp turns are made with difficulty as indicated by the many broken drawbars. A decision as to the most satisfactory design can be reached only after thorough tests of different types.

Gun-Mounts

In the opening paragraphs of this paper reference was made to the recommendations of the Westervelt Board that wheeled trailers should be supplied, or trailer wheels incorporated in track-laying vehicles, in order that they might be towed at high speed, on good roads, by trucks. We have two types which obviate this requirement, the combined wheeled and track-laying and the high-speed track-laying vehicles. The first is exemplified by the Christie type, the second by the Division artillery tractor and the 75-mm. self-propelled gun-mount. The use of a separate wheeled trailer is no longer considered for moving tractors and self-propelled gun-mounts over good roads at high speeds.

The self-propelled gun-mount shown in Fig. 9 is a Holt caterpillar. The track rollers have rubber cores and are rubber-tired, the driving sprocket and idler are rubber-tired and the track has rubber pads inserted in each

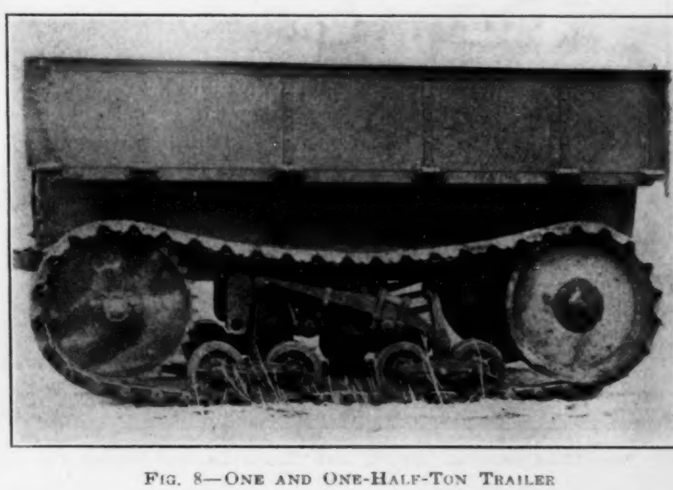


Fig. 8—One and One-Half-Ton Trailer

FIG. 9—SELF-PROPELLED MOUNT FOR 75-MM. GUN CLIMBING A BANK

shoe. According to the builder this track has shown surprising durability; after 600 miles' travel it shows slight wear, and it is thought that it will outwear an all-steel track. We are told that this mount can sustain speeds up to 25 m.p.h. on good roads and makes no more noise when running at this speed than a heavy solid-tired truck. It has all the climbing and maneuvering ability of the tractor and will go, it is stated, anywhere its driver has nerve to take it.

The combined wheel and track-laying Christie-type mount for the 155-mm. gun has shown that it possesses merits to justify its issue to the artillery for a service test. One of these mounts was exhibited at the Summer Meeting of the Society at Ottawa Beach, Mich., in 1920. A view showing the mount crossing a sharp ridge or bank, in which the action of the track and track-supporting wheels are clearly brought out, is given in Fig. 10. The latest design of this mount weighs 38,500 lb. complete with the gun, the overall length including the gun is 236 in. and the width is 112 in. The 120-hp. engine gives speeds ranging from $1\frac{1}{2}$ to 15 m.p.h., the latter on wheels, the maximum speed on tracks being somewhat lower. Fifteen miles per hour can be exceeded

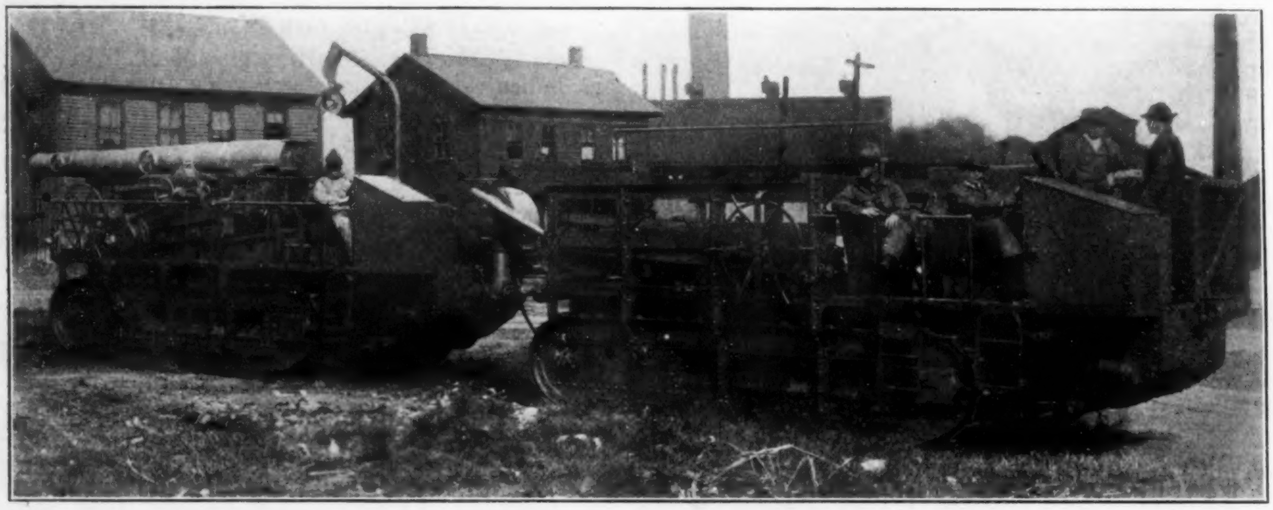


FIG 11—GASOLINE ELECTRIC SELF-PROPELLED MOUNT FOR 240-MM. HOWITZER

FIG. 10—COMBINED WHEEL AND TRACK-LAYING MOUNT FOR 155-MM. GUN

under favorable road conditions by speeding up the engine.

This combined wheel and track-laying type of vehicle, while not considered as the ultimate, is a most interesting development, but its abilities have not been so rigorously tested as those of the tracklayer. When it is operated as a wheeled vehicle, it is steered by the front wheels, like a truck; as there is no differential, care must be taken in making short turns to release the clutch controlling the inner driving-wheel. The tracks can be taken off or put on in a very short time by a trained crew. When not in use they are carried on the track-supporting shelves on either side of the mount. Mechanism is provided for raising and lowering the center wheels of the mount. These are raised free of the ground when traveling as a wheeled vehicle, but lowered to take a large part of the load when operating on its tracks. When the track is in use the steering-knuckles are securely locked and the mount steered by the clutches and transmission in the usual manner.

In addition to this 155-mm. mount there are being built mounts of a similar type for Division and anti-

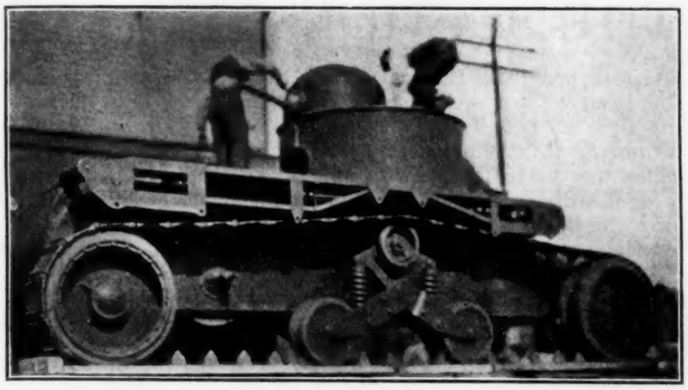


FIG. 12—COMBINED WHEEL AND TRACK-LAYING TYPE OF TANK

aircraft guns. The Ordnance Department has two types of self-propelled mount for the 240-mm. howitzer in which the powerplant and the mount are on a single vehicle. The weight of these vehicles, 106,000 lb., is so great that their use is limited. It is doubtful whether this line of development will be continued.

There is a third type of mount for the 240-mm. howitzer which has advantages that may justify further development. This is the gasoline-electric type, consisting of two vehicles illustrated in Fig. 11. The first carries the 150-hp. engine and generator and a supply of ammunition; the second is the gun-mount. Each unit has two 70-hp. electric motors, one for each track. When traveling on ordinary roads the two vehicles are coupled by a drawbar and connected by an electric cable. The second vehicle can be towed by the first or the motors of both vehicles used, as required by road conditions. If the going is so difficult that the power available will not suffice for both vehicles, they can be moved one at a time. Either vehicle can maneuver separately in bad going or when being placed in firing position. About 200 yd. of cable is carried for this purpose. While this system of electric transmission has not been as thoroughly tested as the mechanical transmission, it offers a satisfactory solution for heavy self-propelled mounts.

TANKS

At the close of the great war the United States found itself with a small number of British tanks of various models, several hundred Renault 6-ton tanks of both American and French manufacture and 100 partially completed Mark VIII tanks. These last, weighing about 40 tons each, have been completed during the past year. They were designed primarily for crossing the extensive trenches of the Hindenberg line and while they did not get a chance to show what they could actually do, tests indicate that they are very successful. The pilot Mark VIII tank has a record of over 200 miles at an average speed of about 4½ m.p.h. without extensive repairs and with, the possible exception of spark-plugs, relatively few replacements.

FIG. 13—STAFF CAR WITH CABLE SUSPENSION TRACK

Tank warfare is so new that its demands have not crystallized, but the present tendency is toward a smaller tank than the Mark VIII but larger than the 6-ton Renault. Two such types are being produced. One, the combined wheel and track-laying Christie type by the Front-Drive Motor Co. of Hoboken, N. J., is shown in Fig. 12. This tank is about 22 ft. long overall, weighs about 16 tons and is equipped with a 120-hp. engine. It is expected to give a speed of 15 m.p.h. at normal engine speed, when traveling on wheels, on good roads. The large center wheels of the 155-mm. gunmount have been replaced by track-rollers, which resemble in principle at least those of the Ordnance Department's 2½-ton artillery tractor model 1920. As originally laid down this tank had but one center wheel on each side, in place of the two used in the 155-mm. self-propelled gun-mounts.

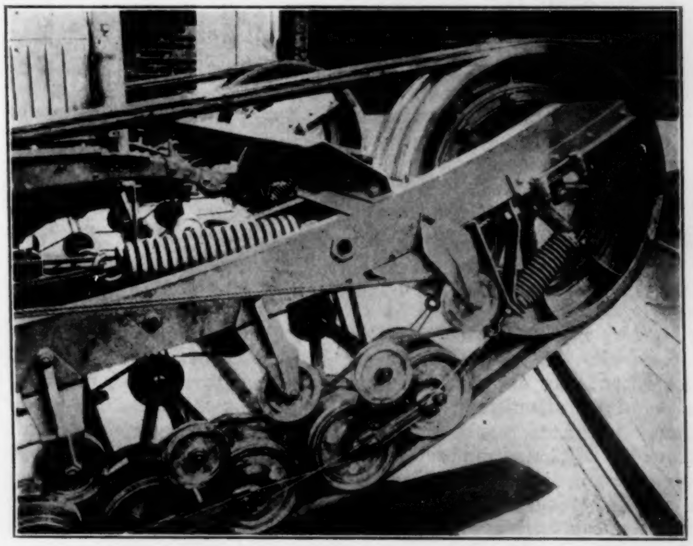


FIG. 14—DETAILS OF THE CABLE SUSPENSION TRACK

This single wheel did not function in a satisfactory manner in the early trials and was replaced by the construction shown. These track-rollers are connected with the transmission so they can be raised or lowered by the driver with no more effort than depressing a pedal. This arrangement is to facilitate easing over sharp crests. It has performed some interesting stunts but has not been subjected to a formal test.

The Ordnance Department is designing and building two medium-sized tanks, one with a track of conventional design and the other with a cable-suspension track. The latter is the invention of Major Johnson, an officer of the British tank corps, and if rumors are to be believed British tanks equipped with tracks of this type are being run at speeds as high as 30 m.p.h. The Ordnance Department has at Aberdeen Proving Ground a White staff car equipped with a fabric track and cable suspension built in England from Major Johnson's design. Some idea of this form of suspension can be obtained from Fig. 13. This particular vehicle has not proved a success so far but it is believed that with a few changes and adjustments it can be operated successfully as an experimental vehicle. The close-up of the front end of the White car in Fig. 14 shows the details plainly.

ACTIVITIES OF THE SECTIONS

Sections Calendar

BOSTON
April 22—Storage Batteries. F. J. Stone. Head Lights.
May —Meeting in Worcester, including plant inspection trip.

BUFFALO
April 19—Carbureter Performance. F. C. Mock.

CLEVELAND
April 15—Aluminum in Engine Construction. Lawrence Pomeroy.
May 20

DAYTON
May 17

DETROIT
April 22

METROPOLITAN
April 14—Low-Grade Fuel Carburetion. R. H. Beach.

MID-WEST
April 11—Automatic Charging of Batteries. H. M. Beck.

MINNEAPOLIS
April 6—Repair Equipment.

WASHINGTON
April 1—Aeronautic Meeting. Brigadier-General Wm. Mitchell, Major H. W. Harms.

ALL of the Sections will elect officers for their next administrative year at the meetings this month. The Sections delegates to the annual Nominating Committee of the Society will also be selected at the April meetings. The Nominating Committee is composed of one representative elected by each Section, together with three members from the Society at large elected at the Summer Meeting. This Committee is then immediately organized and proceeds with the selection of nominees for the Society offices next falling vacant, culminating in the election of officers for 1922.

Since the Sections have so large a part in the selection of Society officers through the working of this Committee, it is very desirable that the delegates chosen should be men thoroughly conversant with the policies of the Society, and familiar with the records of men who may be proposed as candidates for office.

RECENT MEETINGS.

Good Roads and Equipment was the subject presented by C. O. Wold at the Minneapolis Sections meeting held on March 2. The Mid-West Section at its meeting on March 11 listened to a paper on Valve Actions and Engine Design by Chester S. Ricker and John Moore. H. G. Farwell talked on Brakes before the Metropolitan Section on March 16. He had returned from Europe shortly theretofore, and reported the observations he had made there with regard to current practices connected with his professional contribution to the members. A moving picture was shown during the evening which was particularly interesting to all those who have had to deal with the problem of industrial relations. This film gave the history of the Bantam Ball Bearing Co., which has been one of the pioneer companies in working out a system of cooperative management with its employees. J. S. Marvin, assistant general manager of the National Automobile Chamber of Commerce, in an after-dinner address outlined the present activities of that organization.

Economic Automotive Design was the subject of one of the papers given before the Washington Section on March 18. This paper was presented by B. B. Bachman, chairman of the Standards Committee, and the vice-president of the Society for Motor-Car Engineering. At the same meeting Economic Highway Design and Maintenance was discussed by H. G. Shirley, secretary of the Federal Highway Council and formerly chief engineer of the Maryland Highway Commission.

The Pennsylvania Section joined with the Engineers Club of Philadelphia in holding on March 22 a meeting at which Richard Spillaine of the Financial Department of the Philadelphia *Public Ledger* spoke on How the Engineer Can Best Capitalize Himself.

A comprehensive session on Post-War Progress in Aviation was held at Dayton on March 22 by the Section of the Society just established there. G. M. Williams. general manager of the Dayton-Wright Airplane Co., spoke on the actual accomplishments in commercial aviation since the armistice. Having returned recently from Europe, where he inspected many commercial airplane lines in operation, he was able to make an interesting comparison between European and American progress. C. F. Taylor, engineer in charge of the Powerplant Laboratory at McCook Field, covered the developments in powerplants and fuels that have made possible flights at great altitudes, increase in compression ratios and greater engine size and efficiency. F. W. Caldwell, of the propeller branch of the Air Service, spoke of the improvements made in his field of engineering endeavor, including reversible propellers and the use of steel in the manufacture of propellers. Lieut. C. N. Monteith, chief of the Airplane Section, gave a résumé of the newer phases of airplane construction, such as all-metal planes, internally-braced planes and high-speed aircraft.

The Cleveland Section held a dinner and technical meeting on March 18.

During the Automobile Show at Boston the progressive Section of the Society established there held a meeting on March 17. George M. Graham, vice-president of the Pierce-Arrow Motor Car Co., gave an illuminating talk on The Business Situation.

The Relation Between the Automotive Industry and Department of Engineering Research at the University of Michigan was the subject Prof. A. E. White treated at the meeting of the Detroit Section held on March 25. This is a matter of peculiar interest at this time because of the prospective increased activity of the Society in research matters.

SOME EXPERIMENTS ON THICK WINGS WITH FLAPS

IN the paper by C. D. Hanscom entitled Some Experiments on Thick Wings with Flaps which was published in the March issue of THE JOURNAL an error was made in connection with the characteristic curves of the H1, H3a, H3b wing sections which appear on pages 271 and 272. In all four sets of curves the ordinates at the left side should have been marked K_y instead of K_x and the ordinates at the right should have been lableed K_x instead of K_y, L/D. The values of the L/D are the same as those given at the left of the chart except that in this case the decimal point should be moved four places to the right giving a whole number having the same figures as those given in the last two decimal places. This change in the ordinates, of course, necessitates a corresponding change in the characteristic curves, it being necessary to transpose the inscriptions K_x and K_y in each case.

Current Standardization Work

THE changes which occur in the personnel of the Standards Committee following each Annual Meeting of the Society cause a short interval to elapse before the various Divisions are functioning with their usual activity. The work for the ensuing year is now well under way and some of the Divisions are busily engaged. A resume of the recent activities of the different Divisions is given below.

Frames Division

A meeting of the Frames Division was held on March 10 in Cleveland at which a general letter was drawn up covering the points on which the Division members desired to obtain information to base future work. Copies of the general letter will be sent at an early date to manufacturers and users interested.

Isolated Electric Lighting Plant Division.

A meeting of the engineering representatives of the isolated electric lighting plant manufacturers was held at the Hotel LaSalle, Chicago, Feb. 2. The primary purpose was to discuss a possible revision of the present S. A. E. standard for the rating of storage batteries for isolated electric lighting plants. As the personnel for 1921 of the Division in question had not been appointed at the time of the meeting, the action taken was unofficial so far as the Standards Committee is concerned, but was intended as a definite guide to the Division, when appointed, as to what it was thought should be done toward making the standard a better one and more generally accepted.

The discussion indicated that the present so-called 72-hr. intermittent rating is used largely for commercial purposes and is misleading to the non-technical mind. A recommendation was passed that the present 72-hr. rating be withdrawn and a continuous 8-hr. discharge rating substituted. While this proposal met with considerable favor, further discussion developed other suggestions, such as a compromise between the present and the proposed ratings, the proposed 8-hr. rating being used with reference to power for mechanical purposes and the present 72-hr. intermittent rating for lighting purposes. The voltages used and the types and methods of rating implements such as flatirons, washing machines and vacuum cleaners were taken up. Since the usual method of rating such apparatus is in watts, it was thought generally that a battery rating could be expressed in watts, but as the element of the time of discharge of the battery must be taken into consideration it was finally decided that each lighting plant manufacturer should study the possibility of using a battery watt-hour rating based on a 20-hr. discharge and have definite data prepared in time for the next meeting, which was tentatively scheduled for April 11 at Chicago. This will enable the S. A. E. Isolated Lighting Plant Division to meet with the Farm Lighting Plant Group of the Gas Engine & Farm Power Association, the spring meeting of which is tentatively scheduled to be held at about the time mentioned. Thus it will be possible to secure more general consideration of the new rating to be suggested by the Division.

Passenger-Car Body Division

An organization meeting of the Passenger-Car Body Division was held on March 11 in New York City. It was decided to concentrate the work of the Division on a small number of subjects which are considered the most important to the passenger-car body builders, assigning the different subjects to Subdivisions in order to facilitate the work.

Non-Ferrous Metals Division

The Subdivision on Die-Casting Alloys held a meeting on March 11 in New York City at which the subject of die-casting alloys was considered in the light of the recommendations made by the Non-Ferrous Metals Division members at the Division meeting in November. Analyses were decided upon for Specifications No. 20, 28 and 29 which will be sent to all the die-casting manufacturers for criticism and, if they meet with approval, will be submitted to the Non-Ferrous Metals Division.

Screw-Thread Division

The Screw-Thread Division held a meeting on March 12 at the Old Colony Club in Detroit. This first meeting of the Division was given over almost entirely to a general consideration of several subjects assigned by the Council. Subdivisions were appointed to carry on the work in connection with the several subjects until the next meeting.

Stationary Engine Division

Although the Division for 1921 had not been officially organized at that time invitations were sent to about 18 stationary engine builders or their representatives to attend a meeting of the Stationary Engine Division at Chicago on Feb. 1. It has been felt for some time that much could be done toward deriving and establishing suitable engineering standards applicable to stationary internal-combustion engines, particularly those employed for agricultural purposes. While this type of powerplant is somewhat limited as regards mobility it has come into general use for a number of purposes, such as driving lighting plants and operating milking and grinding machines, saws and other equipment. Since the work which this type of engine is called upon to perform is of a very rugged nature and it must operate with a minimum of attention, care and cost, the same degree of refinement has not been attained in its design as in the case of the automobile and other types used for transportation purposes. There are many features, however, which if properly standardized will mean large savings to the builders and a lower cost and a decrease in the amount of time lost by the operator in replacements and operation. The possibilities of standardizing certain features were discussed at this meeting and a general plan of procedure prepared.

At the meeting the subjects of belt speeds and lubricators and grease cups were considered. In connection with the former, charts and tables which were submitted by those in attendance including a number of very representative engine builders showed a wide divergence of belt and engine speeds. This it was stated not only caused much confusion in connection with the designing of power-driven farm equipment but was generally unnecessary. The tentative proposal for standardizing belt speeds which was prepared as a result of the meeting is given in the accompanying table.

TENTATIVE PROPOSAL FOR STANDARD BELT SPEEDS

Nominal Engine Rating, hp.	Belt Speed, ft. per min.
To and including 1½	600-650
1¾-2½	650-750
3-4	800-1,000
5-7	1,500-1,700
8-12	1,700-2,000

In arriving at these belt speeds the requirements for relatively low and high-speed driving equipment were considered as well as the differences in engine speeds and pulley diameters. The two latter factors can, of course, be left to the judgment of the engine builder, since if a standard belt speed is maintained they do not necessarily affect the operation of the driven apparatus. The members of the Division felt that this tentative proposal should be carefully studied, particularly by agricultural implement manufacturers with reference to its adaptability to their products, bearing in mind that while this proposal is intended to apply as far as possible to existing equipment, it is primarily intended as a means

of bringing widely differing practices together when new equipment is designed and built.

As considerable trouble is experienced by engine builders by the differences in size of the body and sight glasses used on lubricators and grease cups, the Division is obtaining data from the manufacturers of these parts with the view to establishing a standard method of numbering the various sizes and standardizing the capacity and pipe connection dimensions for each size. As grease cups are used on some engines in places where others use lubricators, it is planned to include grease cups in this program.

The work most actively in progress has been assigned to 10 Subdivisions to facilitate the necessary investigation and preparation of a report to the Division at its next meeting, which has been tentatively scheduled to be held in Chicago on April 8.

Result of Standards Letter Ballot

At the Annual Meeting of the Society held on Jan. 11 the 32 recommendations of the 12 Divisions of the Standards Committee reporting were approved for final presentation to the voting members of the Society. These were adopted in their entirety by the letter ballot which closed on March 12. The reports on which this action was taken were printed on pages 169 to 199 inclusive in the February issue of The Journal.

The complete vote on the recommendations is tabulated below. The first column gives the number of affirmative votes cast; the second, the negative votes; and the third, the number of members who did not vote either way.

Aeronautic Division

Turnbuckles	128	0	268
Special Report of the Aeronautic Division on the Regulation of Commercial Air Navigation	120	0	276

Ball and Roller Bearings Division

Shaft and Housing Fits and Tolerances for Ball Bearings	226	7	163
Annular Ball Bearings, Separable (Open) Type	229	3	164
Annular Ball Bearings, Wide Type	232	1	163
Angular Contact Ball Bearings	230	3	163

Electric Transportation Division

Electric Vehicle Storage Battery Jars	118	0	278

Electrical Equipment Division

Storage Batteries	199	9	188
Fuses and Fuse Clips	211	1	184
Spark-Plug Tests	225	4	167
Magneto Dimensions	222	0	174
Starting-Motor Pinions	224	4	168
Brushes	198	3	195
Addition of Electrical Appliances	208	1	187

Engine Division

Mufflers	196	18	182
Flywheel Housings	227	2	167
Fan Belts and Pulleys	223	1	172
Carbureter Intakes	229	1	166
Carbureter Air Heaters	227	3	166

Miscellaneous Division

American Standard Taper Pipe Threads	247	1	148
Oil and Grease-Cup Threads	232	4	160

Motorcycle Division

Spokes and Nipples	81	1	314
Motorcycle Wheels and Rims	85	1	310
Motorcycle Controls	75	2	319

Non-Ferrous Metals Division

Non-Ferrous Metal Specifications	220	1	175

Radiator Division

Cast Radiators	183	6	207
Passenger Car Radiators	197	2	197

Tire and Rim Division

Wood Felloe Dimensions for Pneumatic Tire Rims	175	1	220

Tractor Division

Tractor Belts and Pulleys	140	3	253
Tractor Engine Governors	146	0	250

Truck Division

Rim Clamp Bolts	159	3	234
Wood Spokes for Passenger Car Wheels	158	4	234

Of the 2729 ballots mailed to the voting members, 396 valid ballots were cast or 14.5 per cent. This is an increase of 3 per cent over the August, 1920, and 1.5 per cent over the March, 1920, letter ballots.

Transmission Division

A meeting of the Transmission Division was held on March 14 in Detroit at which the regular Division subjects of clutch facings, gear-tooth pressures and transmission drives for speedometers were studied. The subject of clutch-release thrust ball-bearings was considered, members of the Ball and Roller Bearings Subdivision on Thrust Ball-Bearings attended the meeting to discuss this subject jointly with the clutch manufacturers. The basis of the deliberations was the consolidated list of sizes used in the automotive industry during the year 1920, which was drawn up at a meeting of the Thrust Ball-Bearings Subdivision held early in January. It was felt that the standardization should be restricted to only the boundary dimensions and the ball sizes. The consolidated list of sizes discussed at the meeting is given in the accompanying table.

CONSOLIDATED LIST OF CLUTCH-RELEASE TYPE THRUST BALL-BEARINGS USED IN THE AUTOMOTIVE INDUSTRY DURING 1920

No.	Bore, in.	Outside Diameter, in.	Width, in.	Size of Balls, in.
1	1	1.90	0.636	5/16
2	1⅜	2¼	0.6811	5/16
3	1⅜	2.695	11/16	5/16
4	1 7/16	2 9/16	11/16	5/16
5	1⅝	2¾	11/16	5/16
6	1¾	3 3/32	13/16	5/16
7	1 13/16	3	¾	5/16
8	2	3½	11/16	5/16
9	2	3 3/16	¾	5/16
10	2	2 15/16	¾	5/16
11	2¼	3 5/16	¾	5/16 or ⅜
12	2¼	3 7/16	¾	
13	2⅝	3 31/32	13/16	5/16
14	3¼	4⅛	11/16	5/16
15	3½	4.53	⅞	5/16

Truck Division

The discussion at the Standards Committee meeting in January with regard to the proposed standardization of front hubs for motor trucks was printed together with a resolution by the Truck Division of the Standards Committee as to the course to be followed by the Division.

A meeting of axle, bearing and wheel manufacturers was called by C. C. Carlton, president of the Wood Wheel Manufacturers' Association at Detroit, March 3, to discuss ways and means for the continuation of the hub standardization and the possibility of including both ball and roller bearings in this program. A subcommittee of ball-bearing manufacturers, of which T. V. Buchwalter was appointed chairman, reported that it seemed advisable for the subcommittee to take more time in the preparation of its report on the ap-

(*Concluded on page* 385)

OBITUARIES

William H. Van Dervoort, a past-president of the Society and president of the Root & Van Dervoort Engineering Co., died at his home in Moline, Ill., Feb. 25, aged 51 years. His death was the result of an illness contracted while he, as a member of a commission of five American manufacturers representing the National Industrial Conference Board, was touring Europe early in 1919 to assist in the reconstruction of destroyed factories. While his health was never really good since his return from Europe in May, 1919, it improved slightly about a year ago, but at the commencement of the past winter Mr. Van Dervoort became ill and for months had been at the point of death.

Mr. Van Dervoort was born Feb. 28, 1869, at Ypsilanti, Mich. He attended the Michigan Agricultural College at Lansing as a student in the mechanical engineering department and after being graduated in 1889 with the degree of bachelor of science entered Cornell University, from which he was matriculated in 1893 with the degree of mechanical engineer. He accepted a position as assistant professor of mechanical engineering at the University of Illinois and remained there for six years until together with O. J. Root, who had been a classmate at Lansing, he organized the Root & Van Dervoort Engineering Co. to build gasoline engines and manufacture locomotive specialties. Mr. Van Dervoort at that time was vice-president and manager of the company, which was located at Champaign, Ill., but removed to East Moline in 1901. When the Moline Automobile Co. was organized 1903 he became its president and general manager and as new organizations were formed to take care of the various branches of the business he became their head.

Energetically devoted to the advancement of the gasoline engine industry, Mr. Van Dervoort visited South America in the winter of 1912-1913 in the interest of the extension of that trade, a trip that was highly successful. He was president of the Society in 1915 and served as president of the National Metal Trades Association for the years 1916-1917, this being the only instance that this organization has reelected a president. From 1908 to 1911 Mr. Van Dervoort was a member of the committee on management of the American Motor Car Manufacturers' Association and also held many important positions in the National Automobile Chamber of Commerce.

Early in the war, when the British Government enlisted the manufacturing facilities of America, the Root & Van Dervoort plant was chosen for the execution of important shell contracts. Upon the completion of this work Mr. Van Dervoort caused the plants which had been specially equipped for shell production to be closed and the machinery and equipment kept intact and under guard in readiness for the time when they might be called upon to serve this country. After the entrance of the United States into the war these plants were placed in operation and manufactured 8-in. gas shells for the War Department and 4-in. shells for the Navy Department. Soon after the United States entered war, Mr. Van Dervoort was appointed a member of the Munitions Standards Board and was selected by the manufacturers to act as a member of the National War Labor Conference Board, he later being appointed a member of the United States War Labor Board by President Wilson. During the war he gave practically all his time to work for the Government.

In addition to his activities as an engineer, Mr. Van Dervoort was widely recognized as an authority on mechanical engineering and was the author of a textbook on Machine Shop Tools and Shop Practice. A number of articles in scientific and technical publications were written by him and because of his technical knowledge and intimate acquaintance with industrial questions he was frequently called upon to address scientific and business organizations.

He is survived by a widow and two daughters. He was elected to Member grade in the Society, in 1908.

All who came in contact with Mr. Van Dervoort admired him for his abilities and loved him for his personal qualities. He was one of the best friends the Society ever had. His conspicuous and valuable service to industry and the nation

WILLIAM H. VAN DERVOORT

constitutes a record that is very dear as well as gratifying to us. His relations with the Society as member and president are cherished as being among our best traditions. Mr. Van Dervoort as a man was an example of fairmindedness and sense of propriety to be followed by all. The conscientiousness and effectiveness that he demonstrated during his administration as president of the Society were very beneficial to and will be long remembered by the members.

William Benton Crisp died at his home in New York City, Jan. 28, aged 60 years. He was born at Fairfield, Anne Arundel Co., Maryland, on April 16, 1860, and entered Johns Hopkins University in 1879 where he took a special course in chemistry and physics. In 1882 he entered the Law School of Columbia University, being graduated therefrom in 1884. He then opened a law office at Baltimore and conducted a successful practice in that city until 1891 when he came to New York City. His specialty was banking, corporation, patent and commercial law.

Mr. Crisp was probably best known to the automotive industry from his connection with the famous Selden patent case in which he represented the interests of the Ford Motor Co. Another important case with which he was connected was the litigation instituted by Wilbur and Orville Wright against the Curtiss Aeroplane Co., which involved the basic patents on airplanes. In that case Mr. Crisp defended Glenn H. Curtiss and the Curtiss organization. His interest in the science of aviation resulted in his being one of the incorporators of the Manufacturers Aircraft Association, which was organized in 1917 and at the time of his death he was one of the trustees of this organization. He is survived by his widow and two sons, one of whom was his partner in the law firm of Crisp, Randall and Crisp. Mr. Crisp was elected to Associate Member Grade in the Society, Feb. 1, 1917.

Dana McGuffey Lasley died in the Parker Hospital, Detroit, Feb. 20, following an operation for appendicitis. He was born at Columbus, Ohio, May 11, 1885, and re-

(*Concluded on page* 385)

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

USE OF THE MACMICHAEL VISCOSIMETER IN TESTING PETROLEUM PRODUCTS. By W. H. Herschel and E. W. Dean. Reports of Investigations Serial No. 2201. Published by the Bureau of Mines, Washington. 12 pages.

The common practice of the petroleum industry is to measure viscosity by instruments of the efflux or capillary tube type, notably the Saybolt universal viscosimeter. They have, however, certain limitations and for special types of work there are notable advantages incident to the use of the so-called torsion type of viscosimeter, the most satisfactory available type of which seems to be that of MacMichael. The report indicates conditions under which this viscosimeter can be used to advantage in the petroleum laboratory and outlines simple methods of operation and calibration.

PROPERTIES OF THE ARC-FUSED METAL. By Henry S. Rawdon, Edward C. Groesbeck and Louis Jordan. Bureau of Standards Technologic Paper No. 179. Published by the Superintendent of Documents, Government Printing Office, Washington. 63 pages.

The results of the investigation here given relate principally to the nature and characteristic properties of the arc weld, and in particular those of the "fused-in" metal. Since the metal of any weld produced by the electric-arc fusion method is essentially a casting, it is apparent that the efficiency of the weld is dependent upon the properties of this arc-fused metal. A considerable number of examinations was made of welds prepared by the electric-arc process and representative of different conditions of welding. In addition to mechanical tests the specimens were examined very carefully with a microscope. The results of the mechanical tests given are of value in that they are indicative of the average mechanical properties which should be expected in electric-arc welds of satisfactory grade and of the shape and size of those examined.

THE SAYBOLT FUROL VISCOSIMETER. By E. W. Dean. Reports of Investigations Serial No. 2215. Published by the Bureau of Mines, Washington. 4 pages.

The Saybolt furol viscosimeter, to be used at a temperature of 50 deg. cent. (122 deg. fahr.), has been adopted by the Bureau of Mines, and the Committee on Standardization of Petroleum Specifications, as official for the testing of "heavy" fuel oils. The features of this instrument are described and the history of its development given.

CARBONIZATION OF LUBRICATING OILS. Bureau of Standards Circular No. 99. Published by the Superintendent of Documents, Government Printing Office, Washington. 44 pages.

The nature and effects of the deposits formed in internal-combustion engines are discussed. It is shown that the term "carbon" is a misnomer, because the deposits consist largely of asphaltic matter. Brief accounts are given of the nature of petroleum oils and of the theories concerning the formation of deposits. The oxidation and cracking of petroleum are discussed in detail. Carbonization tests which depend upon oxidation and upon cracking are next taken up. Full descriptions of the apparatus and procedures for the Waters and Conradson carbon residue tests are given. Distillation methods are touched upon. It is pointed out that there is yet much to be learned upon the whole subject of the lubrication of internal-combustion engines.

THE SHIFT OF THE ANGLE OF NO-LIFT ON PROPELLER AIRFOILS. Air Service Information Circular, vol. II, No. 147. Published by Chief of Air Service, Washington. 3 pages.

Tests were run for the purpose of securing improved conceptions regarding the use of airfoils in propeller design. Evidence regarding a change in the angle of no-lift, depending upon the velocity, has been investigated as having significance in propeller design.

TEST OF REVISIONS IN COOLING SYSTEMS FOR AIR-COOLED CYLINDERS. Air Service Information Circular, vol. II, No. 124. Published by Chief of Air Service, Washington. 18 pages.

Four types of collectors or baffles were made up of welded sheet steel, the object of the design in each type being to direct the flow of the air to the rear of the cylinder, thus reducing the temperature at that location. These were tested and one type selected as most suitable.

BIBLIOGRAPHY OF PETROLEUM AND ALLIED SUBSTANCES IN 1918. By E. H. Burroughs. Bureau of Mines Bulletin No. 189. Published by Bureau of Mines, Washington. 180 pages.

This bulletin, the fourth in a series of petroleum bibliographies being published by the Bureau of Mines, indexes the articles and books published in 1918 on the utilization of petroleum products as well as their production. The internal-combustion engine classification covers 15 pages.

THE DESIGN OF WIND TUNNELS AND WIND-TUNNEL PROPELLERS. By F. H. Norton. National Advisory Committee for Aeronautics Report No. 98. Published by the National Advisory Committee for Aeronautics, Washington. 10 pages.

This is a continuation of Report No. 73 of the National Advisory Committee for Aeronautics and was undertaken for the purpose of supplying further data to the designer of wind tunnels. Particular emphasis was placed on the study of directional variation in the wind stream. It was found that placing radial vanes directly before the propeller actually increased the efficiency of the tunnel to a considerable extent. The placing of a honeycomb at the mouth of the experimental portion was of the greatest aid in improving the flow, but somewhat reduced the efficiency.

SOME ITEMS OF INVESTMENT, EXPENSE AND PROFIT IN COMMERCIAL SHALE-OIL PRODUCTION. By L. H. Sharp and A. T. Strunk. Reports of Investigations Serial No. 2214. Published by the Bureau of Mines, Washington. 3 pages.

Many opinions have been expressed regarding the possibilities of profitably engaging in the manufacture of shale oil. A general outline of the principal items of investment, expense and profit is given in this report for the information of those who have not considered the variety and scope of equipment necessary to commercial production of shale oil.

A HIGH-SPEED ENGINE PRESSURE INDICATOR OF THE BALANCED-DIAPHRAGM TYPE. By H. C. Dickinson and F. B. Newell. National Advisory Committee for Aeronautics Report No. 107. Published by National Advisory Committee for Aeronautics, Washington. 15 pages.

This report describes a pressure-measuring device especially adapted for use in mapping indicator diagrams of high-speed internal-combustion engines. The cards are obtained by a point-to-point method giving the average of a large number of engine cycles. The principle involved is the balancing of the engine cylinder pressure against a measured pressure on the opposite side of a metal diaphragm of negligible stiffness. In its application as an engine indicator the phase of the engine cycle to which a pressure measurement corresponds is selected by a timing device. The report discusses briefly the errors which must be avoided in the development of an indicator for light high-speed engines where vibration is serious and outlines the principles underlying the design of this instrument to be free of such errors. A

detailed description of the instrument and accessories follows, together with operating directions. Specimen indicator diagrams are appended. The indicator has been used successfully at speeds up to 2600 r.p.m., the highest speed engine available for trial. Its sensitivity is approximately that of a standard 6-in. dial gage of the Bourdon tube type.

CAUSES OF CRACKING OF IGNITION CABLE. By F. B. Silsbee. National Advisory Committee for Aeronautics Technical Note No. 32. Published by National Advisory Committee for Aeronautics, Washington. 16 pages.

Experiments are described which show that the cracking at sharp bends, observed in the insulation of high-tension ignition wires after service, is due to a chemical attack upon the rubber by the ozone produced by the electric discharge which takes place at the surface of the cable. Cracking does not occur if the insulating material is not under tension, or if the cable is surrounded by some medium other than air; but does occur even if the insulation is not subjected to electric stress, provided the atmosphere near the cable contains ozone. The extent of cracking can be materially reduced by using braided cable and by avoiding sharp bends.

DESIGN OF STANDARD LUGS. Air Service Information Circular, vol. II, No. 152. Published by the Chief of Air Service, Washington. 11 pages.

This report describes extensive experiments conducted to determine the proper proportions of the lug ends of airplane sheet-metal wing fittings to which the cable and turnbuckle ends attach. Standard lugs are presented which are based on the test results.

PERFORMANCE TEST OF JUNKER SL-6 AIRPLANE WITH 185-HP. B M W ENGINE. Air Service Information Circular, vol. II, No. 173. Published by the Chief of Air Service, Washington. 7 pages.

This report contains dimensional and performance test data of this well-known German metal monoplane with the observations of the test pilots regarding its flying qualities.

DEPRECIATION

ALTHOUGH virtually all of the great nations of Europe have enacted laws prohibiting the payment of dividends before charging off depreciation, until a few years ago the true nature of depreciation was not generally understood in the United States. Many of our courts formerly held that depreciation was not an element of cost and hence should not be deducted from gross earnings. For example, the Supreme Court rendered the following decision: "We are clearly of the opinion that it is not a proper charge. Only such expenditures as are actually made can with any propriety be claimed as a deduction from earnings." That this decision has been inferentially if not actually reversed is apparent from the rulings of the Interstate Commerce Commission in regard to the depreciation of railroad equipment.

As conditions vary so much it is not safe to establish standard rates of depreciation, but each case must be judged on its individual merits in the light of experience. For example, a stone or concrete storehouse may have a life of 50 years or more while a corrugated iron building subject to the shocks of heavy machinery and to the corrosive effects of gases might not be serviceable one quarter of that time. Machinery depreciates more rapidly than buildings, but varies within wide limits. As a rough guide for favorable conditions, a commission of the National Machine Tool Builders Association recommended an annual depreciation from the first cost of 10 per cent on machinery, 5 per cent on frame buildings and 3 per cent on brick buildings.—J. D. Skinner in *Army Ordnance*.

OBITUARIES

(*Concluded from page* 383)

ceived his technical education at the George Washington and Ohio State Universities, being graduated from the former in 1911 with the degree of Bachelor of Science in Mechanical Engineering, while the degree of Master of Science was conferred upon him the following year by the Ohio State University. For two years after being graduated from college he was chief engineer of the Differential Co. and was engaged in the development of a gearless differential. In 1914 he went with the Chalmers Motor Co. as sales engineer and was engaged in the sales promotion work and acted as a connecting link between the sales and engineering departments. He remained there for two years and then entered the service of the Domestic Engineering Co., Dayton, Ohio, as sales engineer. His duties there consisted of sales promotion work and the developing of a sales and service organization.

In 1917 he resigned to enter the service of the Government in the Ordnance Department, being commissioned as a lieutenant and subsequently was promoted to the rank of captain. He was in charge of the Ordnance Experimental Station at Indianapolis and helped to develop the 5-ton artillery tractor. In 1919 he was discharged from the Government service and accepted a position as sales manager of the motor division of the Wellman-Seaver-Morgan Co., Akron, Ohio. At the time of his death he was sales engineer of the Hercules Motor Co., Canton, Ohio. Mr. Lasley, who leaves a widow, was elected to Member grade in the Society, April 9, 1920.

CURRENT STANDARDIZATION WORK

(*Concluded from page* 382)

plication of ball bearings in the proposed standard hubs. It was thereupon decided that the matter be postponed until April 4, at which time the subcommittee would report definitely.

A meeting of the Truck Division was held in Detroit on March 15. The principal subject discussed was motor-truck body-installation dimensions, a tentative Subdivision report, previously sent to the members of the Division, being presented by F. A. Whitten. The report was thoroughly considered in review of criticisms which had been received from representative motor-truck and motor-truck-body builders.

The Subdivision appointed to formulate a standard for the rear shaft-ends of the front shaft of three-joint propeller-shafts reported progress. The members of this Subdivision are J. R. Coleman, chairman, H. B. Knap and J. W. B. Pearce. It is thought that three-joint propeller-shafts have been in use long enough to permit standardizing the particular portion of the shaft mentioned, which it is hoped will result in a great saving to both the manufacturer and to the user.

It was decided that no action should be taken relative to hub standardization until after the meeting of the subcommittee on April 4. A meeting of the Truck Division has accordingly been tentatively scheduled for April 18 to consider the subject of hub standardization further, and if possible to formulate a report to be submitted to the Standards Committee meeting on May 24 at West Baden, Ind.

Applicants *for* Membership

The applications for membership received between Feb. 28 and March 19, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABELL, ROLLIN, mechanical engineer, Duesenberg Bros., *Elizabeth, N. J.*

BACKUS, HAROLD A., head of testing and inspection department, Gallaudet Aircraft Corporation, *East Greenwich, R. I.*

BARBECK, PETER, master mechanic, F. V. F. Machine Works, *New York City.*

BECH, C. O., engineer, Texas Co., *New York City.*

BECK, CHARLES EDGAR, sales engineer, Busch-Sulzer Bros. Diesel Engine Co., *St. Louis.*

BENEDICT, MAJOR CHARLES C., engineering division, Air Service, McCook Field, *Dayton, Ohio.*

BEST, HARRY A., sales representative, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

BLANCHARD, HARRY G., factory manager, Coast Tire & Rubber Co., *Oakland, Cal.*

BOONE, FIRST-LIEUT. MILTON O., motor transport, *Camp Sherman, Ohio.*

BOURNE, PHILLIPS P., chief engineer, Blake & Knowles Works, Worthington Pump & Machinery Corporation, *East Cambridge, Mass.*

BOYNE, WILLIAM K., airplane designer, *Stamford, Conn.*

CALDWELL, WILLIAM E., assistant manager of sales, Cleveland Twist Drill Co., *Cleveland.*

CARTER, CLAUDE, automobile shop foreman, Chris. C. Fausner, *Jamaica, N. Y.*

CARVER, W. L., general manager, Antigo Tractor Corporation, *Antigo, Wis.*

COLE, WALTER C., vice-president and general manager, William N. Albee Co., *Detroit.*

COLLINS, ALFRED S., electrician, Franklin Service & Repair Co., *Brooklyn, N. Y.*

DAVIS, JAMES H., farm engineer, General Motors Research Corporation, *Dayton, Ohio.*

DICHMAN, FIRST LIEUT. ERNEST W., engineering division, Air Service, McCook Field, *Dayton, Ohio.*

DOMONOSKE, ARTHUR B., assistant professor of mechanical engineering and director of shops, University of California, *Berkeley, Cal.*

DRAKE, HARCOURT C., engineer, Sperry Gyroscope Co., *Brooklyn, N. Y.*

DUESENBERG, WESLEY C., assistant superintendent, Kenworthy Motors Corporation, *Mishawaka, Ind.*

DUNCAN, CLEMENT, service manager on carburetion work, Zenith Carbureter Co., *Los Angeles, Cal.*

EDGARTON, LEWIS S., student, Massachusetts Institute of Technology, *Cambridge, Mass.*

EYMAN, ERNEST E., salesman, National Malleable Castings Co., *Cleveland.*

FAUST, WALTER L., student, Stevens Institute of Technology, *Hoboken, N. J.*

FRANZBLAU, JOSEPH, automotive instructor, Army vocational schools, *Fort Slocum, N. Y.*

GEE, HAROLD W., assistant engineer, White Hickory Wagon Mfg. Co., *East Point, Ga.*

GRIGNARD, EMILE E., district manager, Crew-Levick Co., *Philadelphia.*

GUSTAFSSON, BIRGER G., tool and die designer, Arvac Mfg. Co., *Anderson, Ind.*

HEDENE, EDWIN E., chief draftsman, Standard Gas Engine Co., *Oakland, Cal.*

HENDRY, M. JAMES, development engineer, International Harvester Co., *Chicago.*

HITKE, KURT, superintendent, Kenworthy Motors Corporation, *Mishawaka, Ind.*

HOFFMAN, MAJOR E. L., chief of equipment section, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

INSLEY, ROBERT, aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

JACKSON, THOMAS, detailer, Holt Mfg. Co., *Peoria, Ill.*

JOHNSTONE, LLOYD G., JR., general manager, Gilbert Motors Co., *Boston.*

JUDSON, ROSS W., president, Continental Motors Corporation, *Grosse Pointe Park, Mich.*

KING, HAROLD L., mechanical draftsman, tank, tractor and trailer division, Ordnance Department, *Syracuse, N. Y.*

KINSTLER, LEON L., automotive inspector, motors and vehicles section, Army Supply Base, *Brooklyn, N. Y.*

LEVINE, BERNARD, foreman, Packard Motor Car Co., *Long Island City, N. Y.*

LINEK, JOSEPH, JR., foreman, J. Linek, *Maspeth, N. Y.*

LOUGH, HECTOR V., consulting engineer, Hartford Rubber Works Co., *Hartford, Conn.*

LOVE, HARDY C., factory representative, Willard Storage Battery Co., *Cleveland.*

MCCULLOUGH, R. C., director of distribution, Dura Mechanical Hardware Co., *Toledo.*

MCMAHON, JAMES J., designer, Mercury Motors Corporation, *Pittsburgh.*

MANNIEN, ARVO, student, Virginia Vocational High School, *Virginia, Minn.*

MATSON, HUGO WILFRED, Virginia Vocational High School, *Virginia, Minn.*

MIQUELON, P. E., branch manager, Zenith Carbureter Co., *Detroit.*

NEIGHBOR, L. B., experimental engineer, Marseilles Works, *East Moline, Ill.*

NELSON, RALPH N., president, Alloys Motor Parts Mfg. Co., *Tacoma, Wash.*

OLLEY, MAURICE, engineer, Rolls-Royce of America, Inc., *Springfield, Mass.*

OPITZ, F. M., president and factory manager, Perfex Radiator Co., *Racine, Wis.*

PARDEE, HOMER A., vice-president and general manager, Halcomb Steel Co., *Syracuse, N. Y.*

PETERSON, GUSTAF, general manager of sales, Electric Alloy Steel Co., *Youngstown, Ohio.*

POTTER, ALBERT T., chief engineer, Ainsworth Mfg. Co., *Detroit.*

PRICE, JOHN C., mechanical engineer, Jones & Lamson Machine Co., *Springfield, Vt.*

ROSS, ROBERT I., motor truck salesman, Giant Motor Truck Co. Ltd., *Vancouver, B. C.*

RUNCIMAN, H. D., secretary and general manager, Hoover Steel Ball Co., *Ann Arbor, Mich.*

SAKS, IRA, executive, Pennsylvania Piston Ring Co., *Cleveland.*

SATER, CHESTER W., supervisor of transportation, Great Atlantic & Pacific Tea Co., *Jersey City, N. J.*

SAUER, HERBERT F., manager Cleveland branch, Electric Storage Battery Co., *Philadelphia.*

SEWARD, WALTER E., technical school director, Y. M. C. A., *Canton, Ohio.*

SHARP, CLAYTON H., technical director, Electrical Testing Laboratories, *New York City.*

SLAGLE, ALFRED M., designing engineer, Two-Way Plow Tractor Syndicate, *Dayton, Ohio.*

SLOAN, FIRST-LIEUT. KELLOGG, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

STEINBECK, PAUL W., body engineer, H. H. Babcock Co., *Watertown, N. Y.*

THOMPSON, R. M., wholesale manager, Stutz Motor Car Co. of America, *Chicago.*

TIPTON, WILLIAM D., graduate student, Johns Hopkins University, *Baltimore.*

VALIANT, FRANK LIBBEY, sales engineer, Arvac Mfg. Co., *Anderson, Ind.*

WAGNER, HARRY S., draftsman, 19 Pinehurst Avenue, *New York City.*

WEDDLE, ALFRED H., draftsman, Schatz Mfg. Co., *Arlington, N. Y.*

WESSELLS, WALTER B., student, Johns Hopkins University, *Baltimore, Md.*

WILLIS, REX C., owner, Willis Bros., *Yakima, Wash.*

WOOD, J. E., district sales manager, Roller-Smith Co. of New York, *New York City.*

WORK, ROBERT VAN-HORN, student, University of Colorado, *Boulder, Col.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 10 and March 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

AHLENE, C. M. (A) sales and service engineer, Borg & Beck Co., *Moline, Ill.*, (mail) 1832 16th Avenue.

ALLEN, CARLOS H. (M) engineer, New Departure Mfg. Co., 3044 West Grand Boulevard, *Detroit.*

ALTON, DARREL D. (J) designer, Southern Motor Mfg. Association, Ltd., *Houston, Tex.*, (mail) 609½ Fannin Street.

ARMSTRONG, V. M. (A) assistant purchasing agent, Stutz Motor Car Co. of America, Inc., *Indianapolis.*

AUDE, JOHN R. (A) service manager, Chalmers Motor Sales Co., Brooklyn, N. Y., (mail) 211 Knapp Street, *Milwaukee.*

BACON, CHESTER A. (M) chief engineer, Auburn division, Bowen Products Corporation, *Auburn, N. Y.*, (mail) Logan Street.

BAGANZ, HERBERT MORRIS (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 525 North Sixth Street.

BAILEY, CHARLES E. (A) sales and advertising manager, Paragon Motor Car Co., First National Bank Building, *Connellsville, Pa.*

BARTLETT, JOHN W. (A) engineer, Chase Tractors Corporation, Inc., 28 Atlantic Avenue, *Toronto, Ont., Can.*

BARTON, LOY E. (J) student, University of Arkansas, *Fayetteville, Ark.*, (mail) Box 238.

BEVERIDGE, FIRST-LIEUT. JOHN, JR. (S M) chief of engines branch, property division, Air Service, *Washington*, (mail) Copley Courts.

BORGEN, CARL K. (A) Walter M. Murphy Motors Co., 1429 Van Ness Street, *Fresno, Cal.*

BREVAIRE, A. A. (M) chief maintenance engineer, Hare's Motors, Inc., 16 West 61st Street, *New York City.*

BUCK, PORTER A. (J) assistant engineer, Power Truck & Tractor Co., *Detroit.*

BURDICK, RALPH M. (M) American Engine & Airplane Co., *Los Angeles, Cal.*

BURKE, EDMUND E. (E S) student, College of Engineering, University of Michigan, *Ann Arbor, Mich.*, (mail) 901 East Washington Street.

BUTCHER, LOWELL R. (J) experimental engineer, Porter Tractor Co., Newton, Iowa, (mail) 115 North Seventh Street, *East Newton.*

CLARK, REGINALD (A) assistant superintendent, J. H. Williams & Co., *Buffalo, N. Y.*, (mail) 221 North Park Avenue.

CORNELIUS, P. W. (J) tool design, Midwest Engine Co., *Indianapolis*, (mail) 47 Layman Avenue.

CRAMER, V. C. (A) branch manager, F. S. Carr Co., 42 Seldon Avenue, *Detroit.*

DAVIDSON, E. Y., JR. (A) illuminating engineer, Macbeth-Evans Glass Co., *Pittsburgh.*

DE VIGNIER, ROBERT MOTT (M) chief engineer, American Vulcanized Fibre Co., Equitable Building, *Wilmington, Del.*

DICKSEE, CEDRIC BERNARD (M) mechanical engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., (mail) 222 Elm Street, *Edgewood Park, Swissvale, Pa.*

DOWNS, CHARLES W. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 3315 South Street.

DURLER, RUSSELL WALLACE (E S) student, Purdue University, Lafayette, Ind., (mail) 136 Sheetz Street, *West Fafayette, Ind.*

DRUMPELMANN, CARLTON T. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) Sigma Chi House.

EDMUNDS, MARION K. (E S) student, Purdue University, Lafayette, Ind., (mail) 255 South Grant Street, *West Lafayette, Ind.*

FAHNESTOCK, MURRAY (A) technical editor, Trade Press Publishing Co., *Milwaukee*, (mail) 9 Marshall Avenue.

FLETCHER, V. H. (M) chief engineer, Curtis Motor Car Co., 318 Center Street, *Little Rock, Ark.*

FLOSS, CARL WILLIAM (J) draftsman, E. A. Nelson Automobile Co., *Detroit*, (mail) 2440 Parker Avenue.

FOSTER, H. F. (J) Ingersoll-Rand Co., *Athens, Pa.* (mail) Ingersoll-Rand Club.

FREYMAN, ARTHUR LEONARD (E S) student, Purdue University, Lafayette, Ind., (mail) 424 Dodge Street, *West Lafayette, Ind.*

FUNK, JAMES B. (M) branch manager, Champion Spark Plug Co., *Toledo.*

GESCHLIN, JOSEPH (J) production engineer, Duplex Engine Governor Co., Inc., *Brooklyn, N. Y.*, (mail) 294 Van Buren Street.

GIFFORD, ALBERT J. (M) partner, Leland-Gifford Co., *Worcester, Mass.*

GOTTLIEB, MARSHALL D. (J) mechanical engineer, Single Sleeve Motors, Inc., *Chicago*, (mail) 3027 Logan Boulevard.

GRAHAM, JAMES WILSON (M) designer, Hendee Mfg. Co., *Springfield, Mass.*, (mail) Suite 502, 774 State Street.

GREGG, JOHN WILLIAM (E S) student, Purdue University, Lafayette, Ind., (mail) 503 State Street, *West Lafayette, Ind.*

GRINER, RALPH C. (J) chief engineer, United States Tractor & Machinery Co., *Menasha, Wis.*

GRISWOLD, WALTER R. (J) engineer, Packard Motor Car Co., *Detroit*, (mail) 1732 East Grand Boulevard.

GRUENBERG, OTTO (E S) student, Tri-State College, *Angola, Ind.*, (mail) 509 West Maunee Street.

GRUNDY, GEORGE H. (A) general sales manager, Poldi Steel Corporation of America, 115 Broadway, *New York City.*

GUM, WILLIAM BURFORD (E S) student, Purdue University, (mail) Alpha Tau Omega House, 316 Russell Street, *West Lafayette, Ind.*

HARTER, PAUL W. (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 1200 Hartford Street.

HAWISHER, HAROLD H. (E S) student, Purdue University, Lafayette, Ind., (mail) 690 Waldron Street, *West Lafayette, Ind.*

HEDICAN, JOHN EDWARD (E S) student, University of Minnesota, Minneapolis, (mail) Box 540, *Virginia, Minn.*

HEIL, JULIUS P. (A) vice-president, Heil Co., *Milwaukee.*

HOLMES, BRADFORD B. (M) chief engineer, Miller Reese Hutchison, Inc., 51st floor, Woolworth Building, *New York City.*

HOLMGRAIN, E. O. (M) chief draftsman, O. E. Szekely Co., *Moline, Ill.*

IRONSIDE, FREDERICK MARTIN (A) mechanical engineer, E. W. Bliss Co., *Brooklyn, N. Y.*, (mail) 873 Park Place.

JENSEN, MILTON O. (J) engineer, Imperial Brass Mfg. Co., *Chicago*, (mail) 4647 Kenmore Avenue.

KING, LESLIE E. (J) solid and pneumatic tire designer, Kuhlke Machine Co., *Akron, Ohio.*

LEHMAN, HAROLD EDWARD (E S) student, Purdue University, Lafayette, Ind., (mail) Alpha Tau Omega House, 316 Russell Street, *West Lafayette, Ind.*

LEFEVRE, C. D. (M) sections secretary, Society of Automotive Engineers, Inc., 29 West 39th Street, *New York City.*

LINKERT, HOWARD WILLIAM (E S) student, Purdue University, Lafayette, Ind., (mail) 427 State Street, *West Lafayette, Ind.*

LUX, G. J. (M) chief engineer, Detroit Gear & Machine Co., *Detroit*, (mail) 3087 Garland Avenue.

MCCAMPBELL, PAUL R. (M) chief of development, G. & J. Tire Co., *Indianapolis.*

MCCARTY, HARRY HARPER (E S) student, Purdue University, *Lafayette, Ind.*

MCDONALD, HARRY T. (M) designer, Holt Mfg. Co., *Peoria, Ill.*, (mail) 417 California Avenue.

MCNAIR, JAMES TAYLOR (A) assistant service manager, Detroit Cadillac Motor Car Co., *New York City*, (mail) 8 West 62nd Street.

MALM, EDWIN LEMUEL (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) Forest Hill.

MANVILLE, TRACY F. (A) general manager of sales, Columbia Steel & Shafting Co., *Pittsburgh*, (mail) 5822 Marlborough Street, East End.

MAURER, C. N. (A) mechanical engineer, Wisconsin Highway Commission, *Madison, Wis.*, (mail) 1212 West Johnson Street.

MARTY, BENJAMIN F. (A) equipment engineer, Ford Motor Car Co., *Highland Park, Mich.*, (mail) 219 Pilgrim Avenue.

MINER, ROBERT I. (A) sales engineer, Bossert Corporation, Utica, N. Y., (mail) 1513 Ford Building, *Detroit.*

MOGGE, ARTHUR R. (A) manager of advertising and sales production, Gibson Co., *Indianapolis*, (mail) Box 68, Y. M. C. A. Building.

MORITZ, JULIUS HOLLAND (J) designer, Garford Motor Truck Co., *Lima, Ohio*, (mail) 139 South West Street.

MOUGET, MARCEL G. (J) engineer, Western Electric Co., *Chicago*, (mail) 4506 Magnolia Avenue.

MUELLER, FRANK G. (M) chief engineer, Maccar Truck Co., Scranton, Pa., (mail) *Chinchilla, Pa.*

NEAL, JOHN FREDERICK (E S) student, Purdue University, Lafayette, Ind., (mail) 202 Littleton Street, *West Lafayette, Ind.*

NEUSTADT, FRANK (A) chief draftsman, Davis Sewing Machine Co., *Dayton, Ohio*, (mail) 739 Carlisle Avenue.

NORRIS, P. E. (M) production engineer, Westinghouse Union Battery Co., *Swissvale, Pa.*

NYDEN, CLARENCE A. (J) experimental designer, Mitchell Motors Inc., Racine, Wis., (mail) 5043 North Robey Street, *Chicago.*

PETERS, JOHN F. P. (M) superintendent, Northway Motors Corporation, Natick, Mass., (mail) 27 Mount Hope Street, *Roslindale, Mass.*

PFEFFER, JOHN E. (M) mechanical and automotive engineer, Continental Engineering Co., *Chicago,* (mail) Suite 1032, 29 South LaSalle Street.

RHODES, CYRIL (E S) student, Purdue University, *Lafayette, Ind.,* (mail) 525 North Sixth Street.

ROBBINS, ROY MONROE (J) mechanical and automotive draftsman, Comet Automobile Co., *Decatur, Ill.,* (mail) 1159 North Union Street.

ROCKWELL, STANLEY PICKETT (M) metallurgist and chemist, Whitney Mfg. Co., *Hartford, Conn.*

ROGERS, DUDLEY T. (A) sales engineer, American Bosch Magneto Corporation, Springfield, Mass., (mail) 3737 South Michigan Avenue, *Chicago.*

ROLLER, WILLIAM F. C. (J) draftsman, William E. Quimby, Inc., *Newark, N. J.,* (mail) 764 Hunterdon Street.

ROOT, DONALD C. (A) sales engineer, Bridgeport Brass Co., *Bridgeport, Conn.*

ROSS, FRANK (M) superintendent, pressed steel division, Dodge Brothers, Detroit (mail) 162 Monterey Avenue, *Highland Park, Mich.*

ROUALET, ANDREW J. E. (A) experimental laboratory, F. B. Stearns Co., *Cleveland,* (mail) 12412 Euclid Avenue.

SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO. (Aff) *San Diego, Cal.*
Representative:
Klauder, L. M., general superintendent.

SCHARMACH, FRANK WILLIAM (J) designer and layout man, Transport Truck Co., *Mount Pleasant, Mich.,* (mail) 326 North Main Street.

SCHROYER, EDGAR C. (E S) student, Purdue University, Lafayette, Ind., (mail) 453 Littleton Street, *West Lafayette, Ind.*

SCOBIE, VERNON (A) lecturer and instructor, West Side Y. M. C. A. Automobile School, *New York City,* (mail) 13 West 64th Street.

SHEAHAN, FRANK I. (J) Hart Roller Bearing Co., *Orange, N. J.,* (mail) 1 Baldwin Terrace.

SHERWOOD, RICHARD LYON (E S) student, Purdue University, Lafayette, Ind., (mail) 150 Littleton Street, *West Lafayette, Ind.*

SHORT, FRANK (A) expert, Ordnance Department, Frankford Arsenal, *Philadelphia* (mail) 3411 Walnut Street.

SILVERMAN, JESSE (J) manager of technical division, Syracuse Motor Car Co., Inc., 312 West Genesee Street, *Syracuse, N. Y.*

SMITH, CHARLES MACCABE (E S) student, Purdue University, *Lafayette, Ind.*

STOCKER, WILLIAM M. (M) mechanical engineer, Poole Engineering & Machine Co., *Baltimore,* (mail) 2103 Cliftwood Avenue.

STOLTING, FRED J. (J) draftsman, Holt Mfg. Co., Stockton, Cal., (mail) 225 5th Avenue, *Salt Lake City, Utah.*

STRADER, M. E. (J) draftsman, Fairbanks, Morse & Co., *Beloit, Wis.*

SYFAN, ROLLINS C. (A) assistant secretary, Stroud Motor Mfg. Association, *San Antonio, Tex.,* (mail) 807 West Mistletoe Avenue.

TABB, WARNER T. (M) chief engineer, Duplex Engineering Governor Co., Inc., *Brooklyn, N. Y.,* (mail) 194 Clinton Street.

TATU, CHARLES F. (J) 1771 Hertel Avenue, *Buffalo, N. Y.*

TAYLOR, ALBERT LEROY (M) assistant professor and mechanical engineer, University of Utah, *Salt Lake City, Utah,* (mail) 258 University Street.

TAYLOR, PAUL B. (J) engineer, Oakland Motor Car Co., *Pontiac, Mich.,* (mail) 56 Thorpe Street.

TAWRESEY, JOHN S. (J) assistant to chief engineer, Standard Steel & Bearings, Inc., *Philadelphia.*

THOMPSON, EDGAR LAURENCE (E S) student, Purdue University, Lafayette, Ind., (mail) 135 Sheetz Street, *West Lafayette, Ind.*

THOMPSON, J. K. (A) president and general manager, Auto Engineering Co., *Detroit,* (mail) 429 Bagg Street.

THWEATT, CARROLL P. (A) assistant inspection engineer, Eisemann Magneto Co., Brooklyn, N. Y., (mail) 202 East 32nd Street, *Baltimore, Md.*

WHITAKER, NORMAN T. (A) patent lawyer, Whitaker Building, *Washington.*

WILLSHAW, HARRY (A) assistant factory manager, Dunlop Tire & Rubber Goods Co. of America, *Buffalo, N. Y.,* (mail) 39 Granger Place.

ZIMMER R. R. (M) chief engineer, Du Pont Motors, Inc., Foot of Commerce Street, *Wilmington, Del.*